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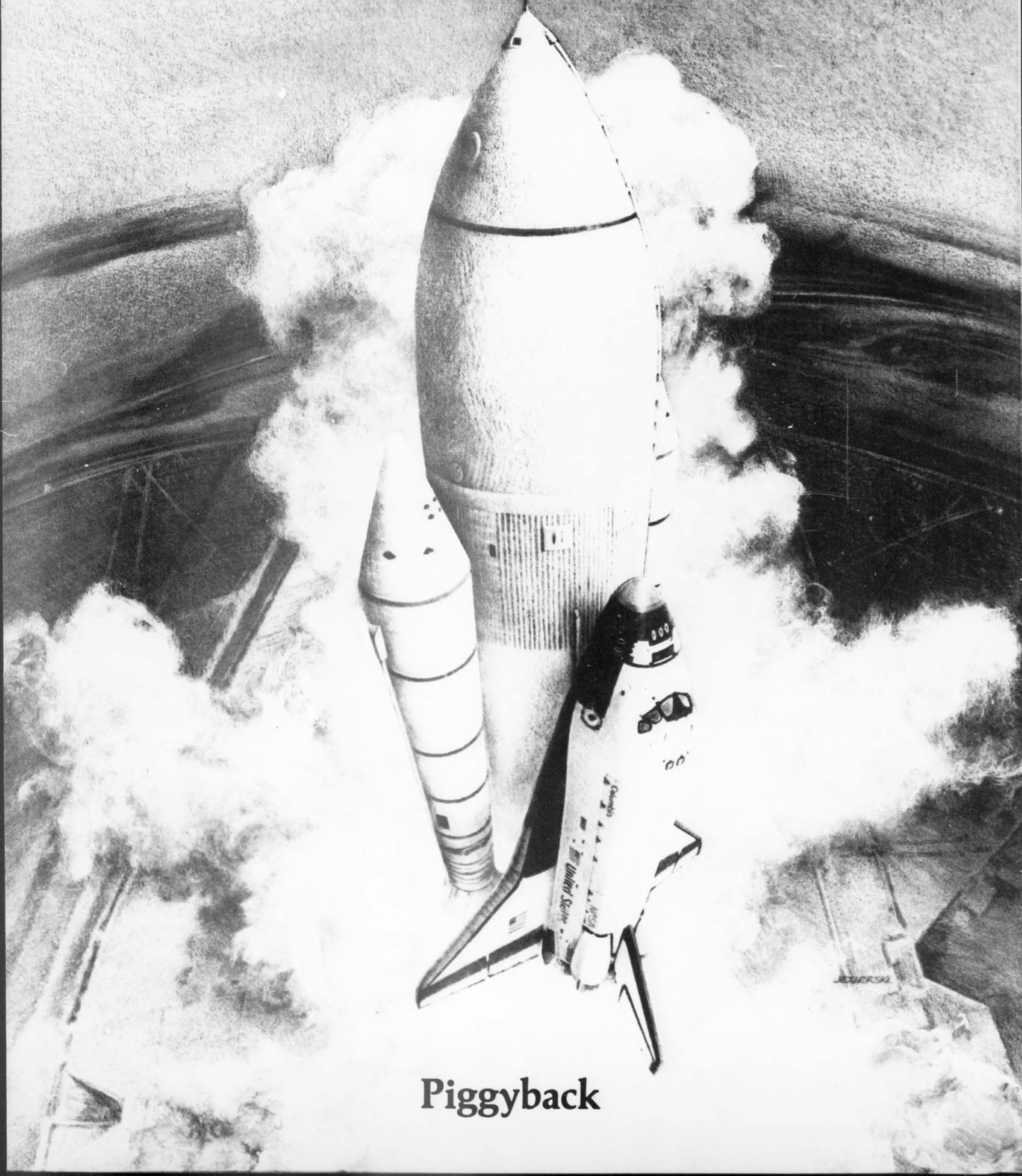
Columbia
United States
NASA
JEZIERSKI

Piggyback

National Air and Space Museum
Noel W. Hinners, *Director*
Walter J. Boyne, *Assistant Director, Resource Management and Operations*

Education Services Division
Janet K. Wolfe, *Chief*

Air & Space
Linda S. DuBro, *Editor*
Holly Haynes, *Editorial Assistant*

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Air & Space
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MUSEUM HOURS
Through Labor Day (September 7), the Museum will be open 10 a.m. to 9 p.m. From September 8 to March 31, hours are 10 a.m. to 5:30 p.m. The Museum is open to the public every day of the year except Christmas. Admission is free.

For brevity, the National Air and Space Museum is often referred to in these pages as NASM. The National Aeronautics and Space Administration is NASA.

Front cover: Launch of the Columbia—STS-1, *a mixed media painting by artist Chet Jezierski, portrays an unusual view of the Space Shuttle* Columbia *as it is launched into space for its first historic flight on April 12, 1981, from Kennedy Space Center.*

Briefing

Piggybacking

Noel W. Hinners
Director, NASM

This issue of *Air & Space* deals with "piggybacking," a concept ringing with nostalgia for many of us. My earliest recollection of a piggyback ride is as a preschooler (2-3 years old?) at the beach. The vision is one of clinging to my Dad's back as he headed down the sand towards the waves of the Atlantic, which frankly, scared the hell out of me. So I look on piggybackers as being small guys hanging on for dear life as they head off on a trip that they could or would not make under their own steam. Now, as then, the clue to success is knowing how and when to get the pig off the back (don't ask what pigs have to do with it. I can't find an origin for the term—dictionaries indicate that it may be a variant of a pick-a-back, origin also unknown). I got pretty adept at sliding off to the beach before getting whopped by a big wave. Similarly, early piggy-backing airplanes and now satellites must be carefully jettisoned from their host ("Get off my back!") at just the right time, and hitchhikers like the Space Shuttle on the Boeing 747 must hold on all the way or suffer dire consequences.

What are the real benefits of piggybacking? The one usually imagined is that of a "free ride." In reality there is no such thing; it being only a question of who pays. In the case of OSCAR ham satellites, the added penalty to the launch rocket is small because the main payload is much larger. OSCAR fits into the weight reserve or margin as it is sometimes called—at most the cost is not much more than that of a little added propellant and attachment structure. For most piggybacking, however prime, the benefit is the flexibility that allows one to do something he otherwise couldn't or could only at greater cost. For example, the Space Shuttle/747 combination obviates having to build the Shuttle at the launch site or having to develop a complex, more expensive modular design convenient for dismantling, trucking, and reassembly.

The piggyback concept extends to major launch systems, including Shuttle's. The Space Shuttle is piggybacking on the solid-rocket boosters even while its own engines burn. In fact, any multistage rocket can be considered multiple piggybacking—as each successive stage burns, it carries the guys above. When a stage burns out, it drops away until the next one takes over. Last guy on wins!

The concept of non-human piggybacking was not invented in, nor is it limited to, aerospace—baby kangaroos have long known a good deal when they see one, and the piggyback rail and sea transport of trailer trucks and containerized cargo have revolutionized the transportation industry.

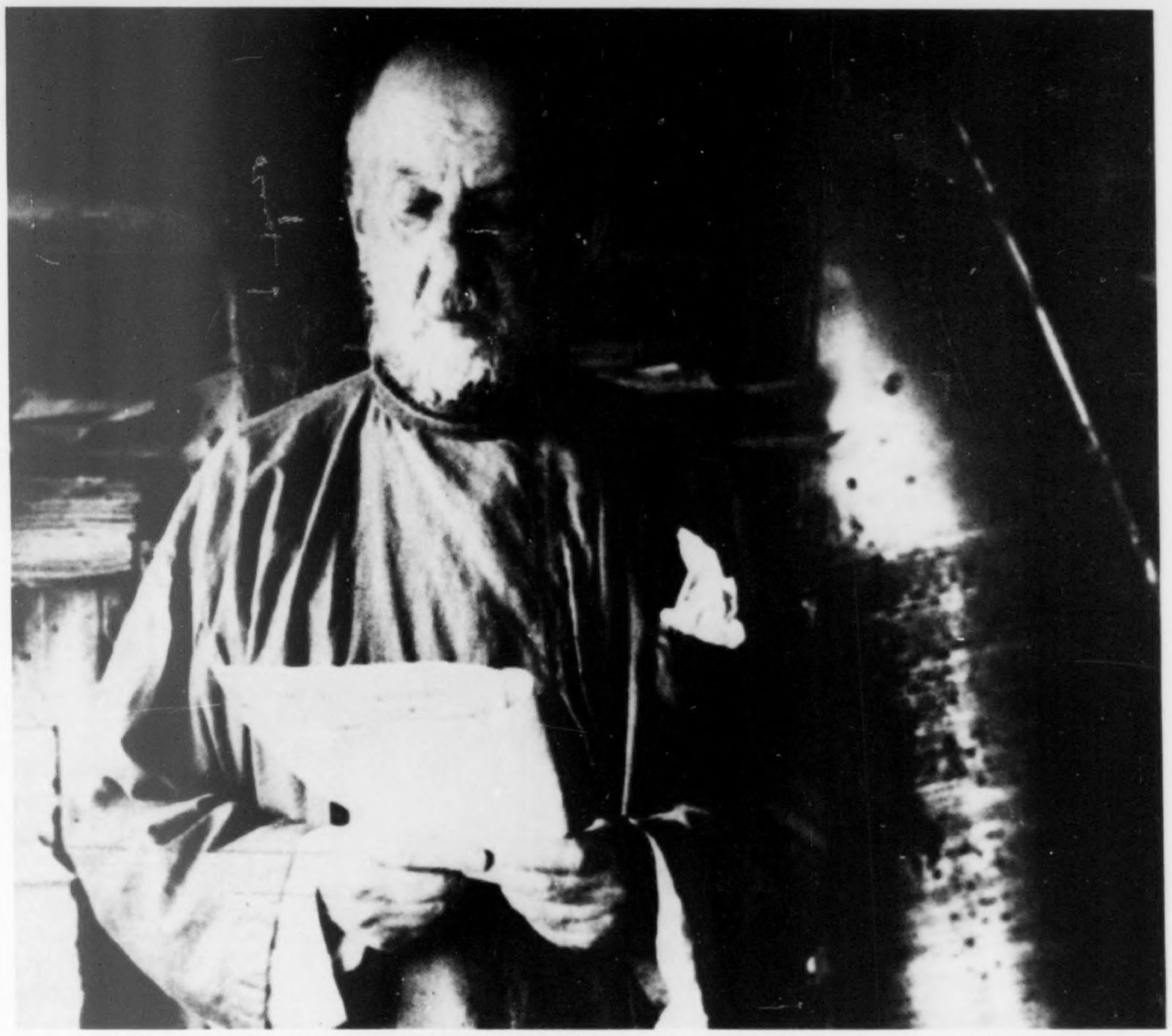
Noel W. Hinners has resigned from NASM effective June 11.

Hinners, 46, was appointed director of the Museum in April 1979. He will leave to become director of the Goodard Space Flight Center in Greenbelt, MD., a part of the National Aeronautics and Space Administration (NASA).

Before joining the Museum, Hinners was associated with NASA for nearly seven years, serving as Associate Administrator for Space Science from 1974-79. Prior to that, he was director of Lunar Programs in NASA's Office of Space Science.

Prior to his work at NASA, he was head of Lunar Science and of the Lunar Exploration Department at Bellcom, Inc., a company that provided systems engineering support for NASA's Apollo program.

Step Rockets: Fireworks to Spaceships



One of the three fathers of rocketry, Russian Professor Konstantin E. Tsiolkovsky, with a model of his metal dirigible, at his workshop at Kaluga, USSR, 1930s.

Frank H. Winter
Historian
Department of Space Science &
Exploration, NASM

The idea was inevitable. Sooner or later all the great space travel pioneers like Russian Konstantin E. Tsiolkovsky, Rumanian Hermann Oberth, and American Robert H. Goddard thought of it—the step rocket.

Place one rocket atop another in successively smaller sizes so that when the one underneath is used up it is expelled, or dropped off, and the next rocket fires upward. In this way, the second, third, and any other stage will have the benefit of traveling at a great speed and high altitude. Multistaging is a logical way of deriving maximum efficiency from rockets in order to place satellites into orbit or to send a probe into deep space. It is a way of getting rid of excess tankage no longer needed as propellants are consumed. Otherwise, if a solitary rocket were used, it would have to be of gigantic proportions. Much more fuel would be needed to reach the orbital velocity required to launch a satellite 27,360 km/hr (17,000 mph.) and for the escape velocity needed to leave the Earth's gravity altogether 40,230 km/hr (25,000 mph.). If the Apollo lunar mission Saturn V rocket had been only one stage, this version would have easily dwarfed the three-stage version, which is already 100 m (364 ft.). It would be like a dinosaur next to a horse!

Step rockets have been called by various names over the years: stage rockets, multistep rockets, and even rocket trains. This idea has a history that is not generally known. Step rockets are at least 450 years old. The earliest firework-makers were always seeking startling new effects for their displays like brighter starbursts and higher-traveling skyrockets. In 1529 one of these gifted artisans, Conrad Haas of Sibui, in what is now Rumania, wrote a manuscript detailing his different experiments with fireworks, which included three-step cardboard gunpowder rockets and also a curious rocket with a little house on it! Was this the first spaceship? No, just another effect.

Other firework step rockets appeared in the firework literature over the centuries. One of them, from mid-17th century Polish artillerist Casimir Siemienowitz, had modern-looking cardboard delta fins.

The 19th century saw its share of step rockets too, but this time there was a more practical reason for them than for mere special effects to amuse crowds. This was the serious business of saving lives. Introduced in the 19th century, the first practical lifesaving rockets were fueled with gunpowder similar to what was used for early fireworks. They were fired from the shore and flew over the masts of ships that had been caught and stranded on offshore rocks. The rockets carried ropes that had grapnel hooks tied to their ends for grabbing onto the ship's riggings. The stranded ship would either be towed to safety within reach of shore or the stranded men would be pulled in by means of pulleys. Some of the lifesaving rocket ropes had lifebuoys or safety belts attached. In 1855, Englishman Edward Mourrier Boxer invented a lifesaving rocket. Two

Robert H. Goddard working on a liquid-fuel rocket, Roswell, New Mexico, 1935.

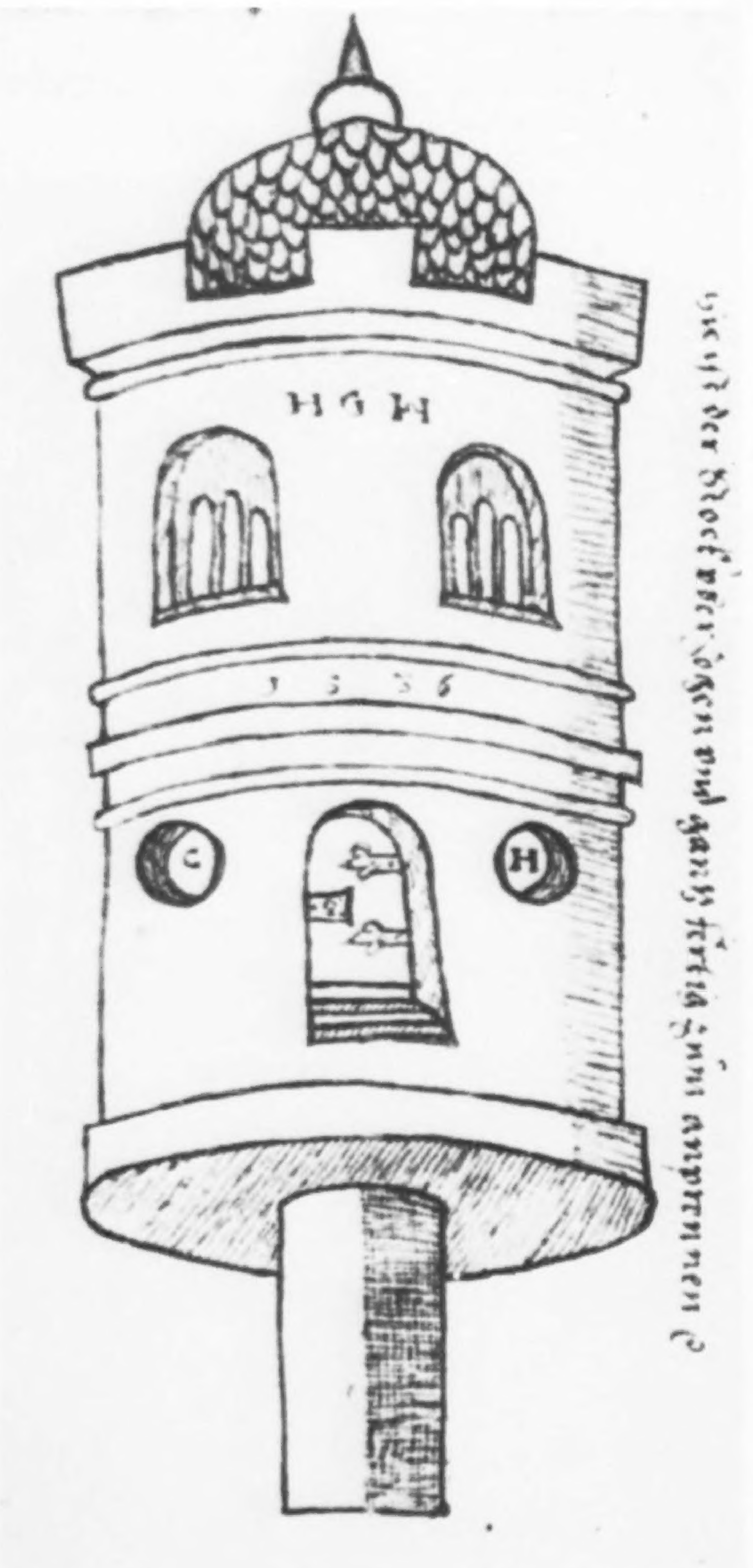
equal-sized rockets were temporarily joined to each other to increase the range of the rockets so that the lifesaving line could reach farther to save human lives.

It is hard to say who first thought of step rockets for spaceflight. Robert Goddard recorded the concept as early as 1909 in one of his notebooks. He elaborated upon the idea later and officially established his claim—at least within the United States—by a U.S. patent (No. 1,102,653, July 7, 1914). Actually, Goddard had not designed a step rocket for interplanetary travel but for carrying a camera for high altitude soundings. He was thinking about upper atmospheric studies similar to those made years later during the 1957–1958 International Geophysical Year (IGY).

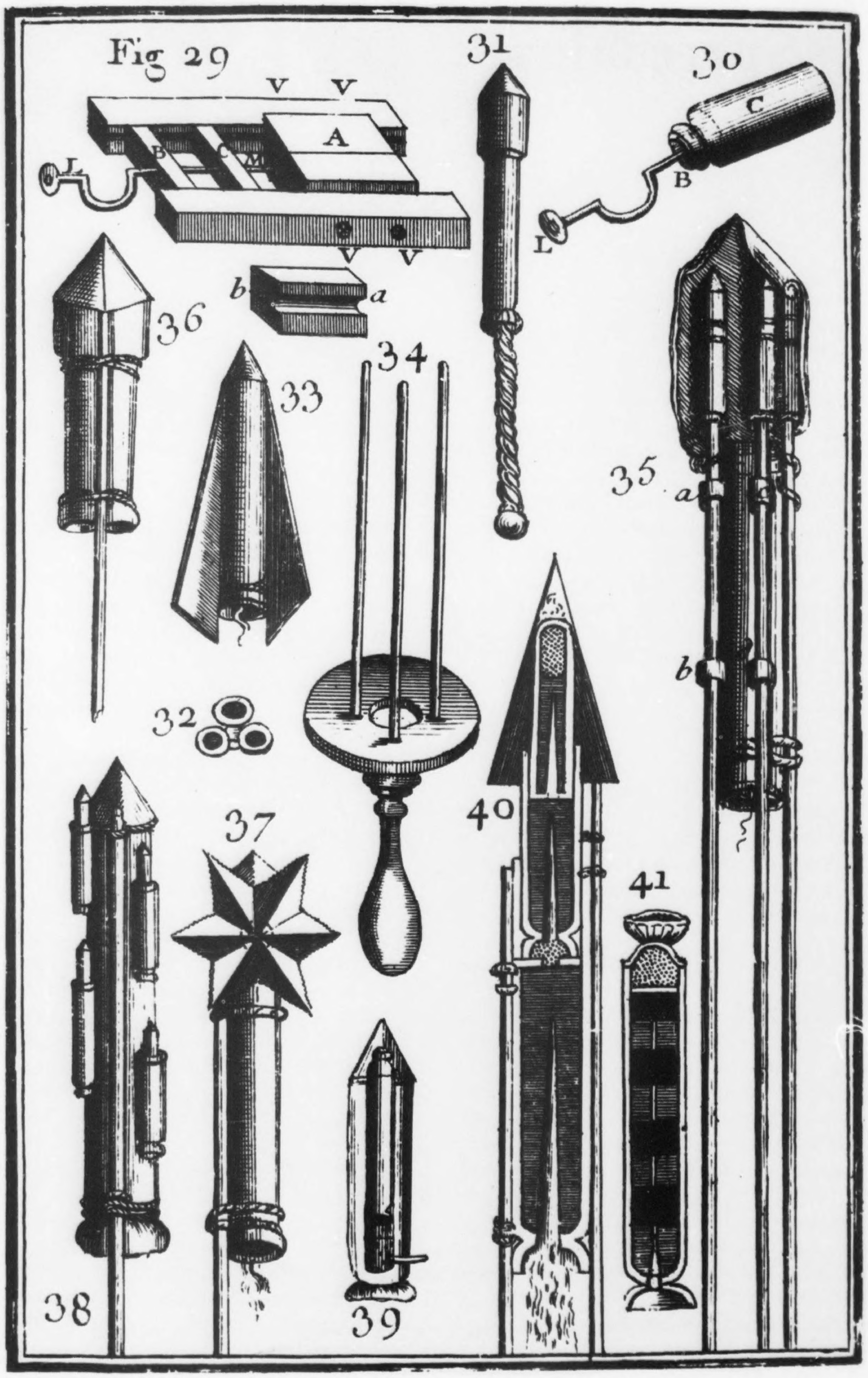
In the meantime, an obscure French medical doctor living in Belgium, Andre Bing, patented a multistep space rocket, which he called "machine for the exploration of the high regions of the atmosphere." This specification (Belgian Patent No. 236,377) was issued June 10, 1911. As far as we know, this farsighted yet unsung space travel pioneer never developed his ideas further.

Goddard spoke at length of the possibility of multistage space rockets in his classic paper, *A Method of Reaching Extreme Altitudes,* published by the Smithsonian in 1919. But his rockets were solid-propelled, not liquid. (Liquid propellants are a much more efficient means of propulsion for space exploration.) Goddard suggested solid-propellant bundles or clusters. The final stage, he said, should contain a certain amount of magnesium powder so that it could explode when it hit the Moon, thereby making its impact easily visible from Earth. In the following year, Goddard turned his attentions to liquid propellants. On March 16, 1926, he launched the world's first successful liquid-fuel rocket. But he never returned to speculating about step systems in his public writings.

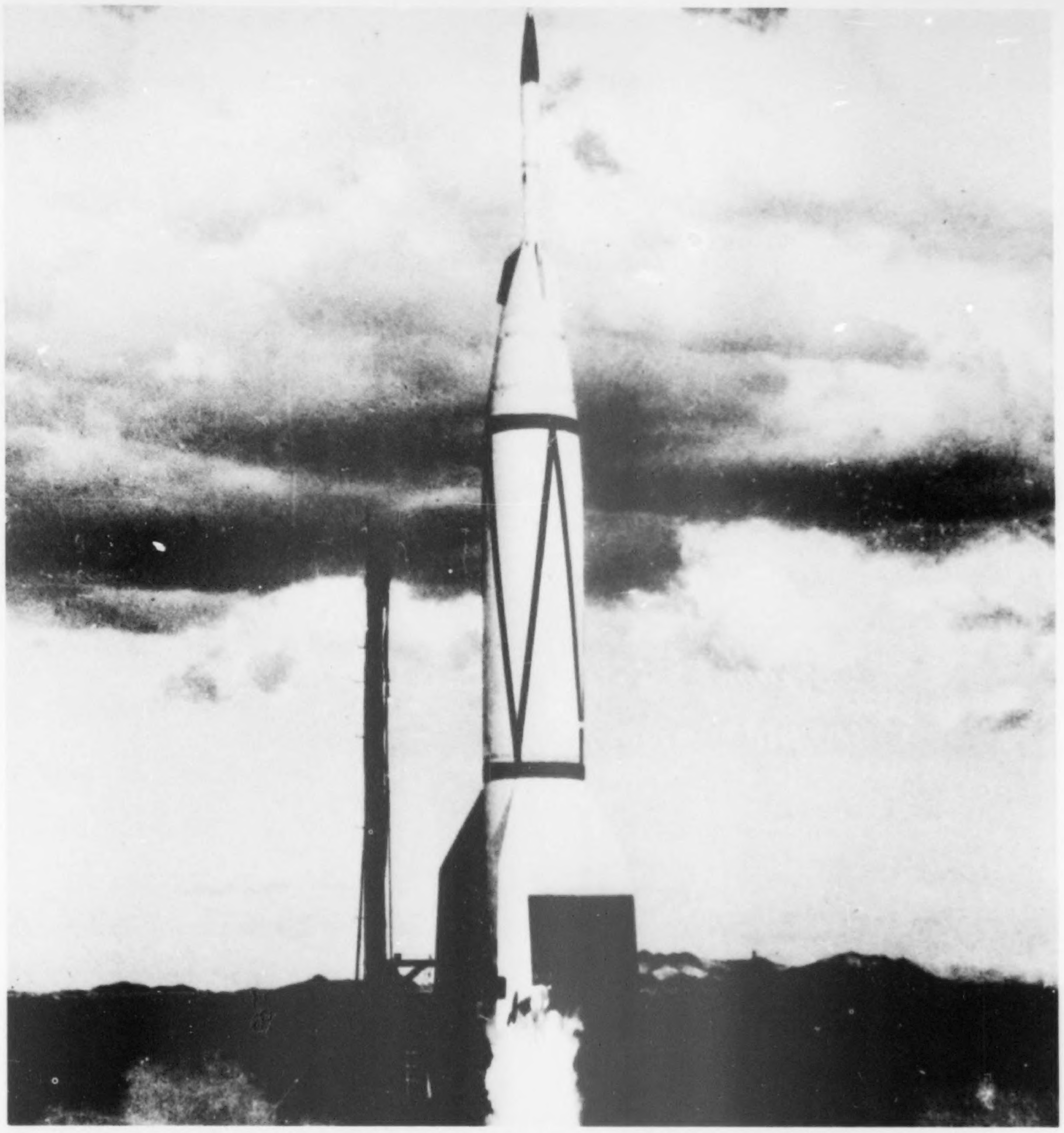
Independently, thousands of miles away, two school teachers also considered the step rocket approach to spaceflight but this time using liquid fuels. One, Hermann Oberth, first published his ideas in his 1923 book *Die Rakete zu den Planetenraümen (The Rocket to Planetary Space).*



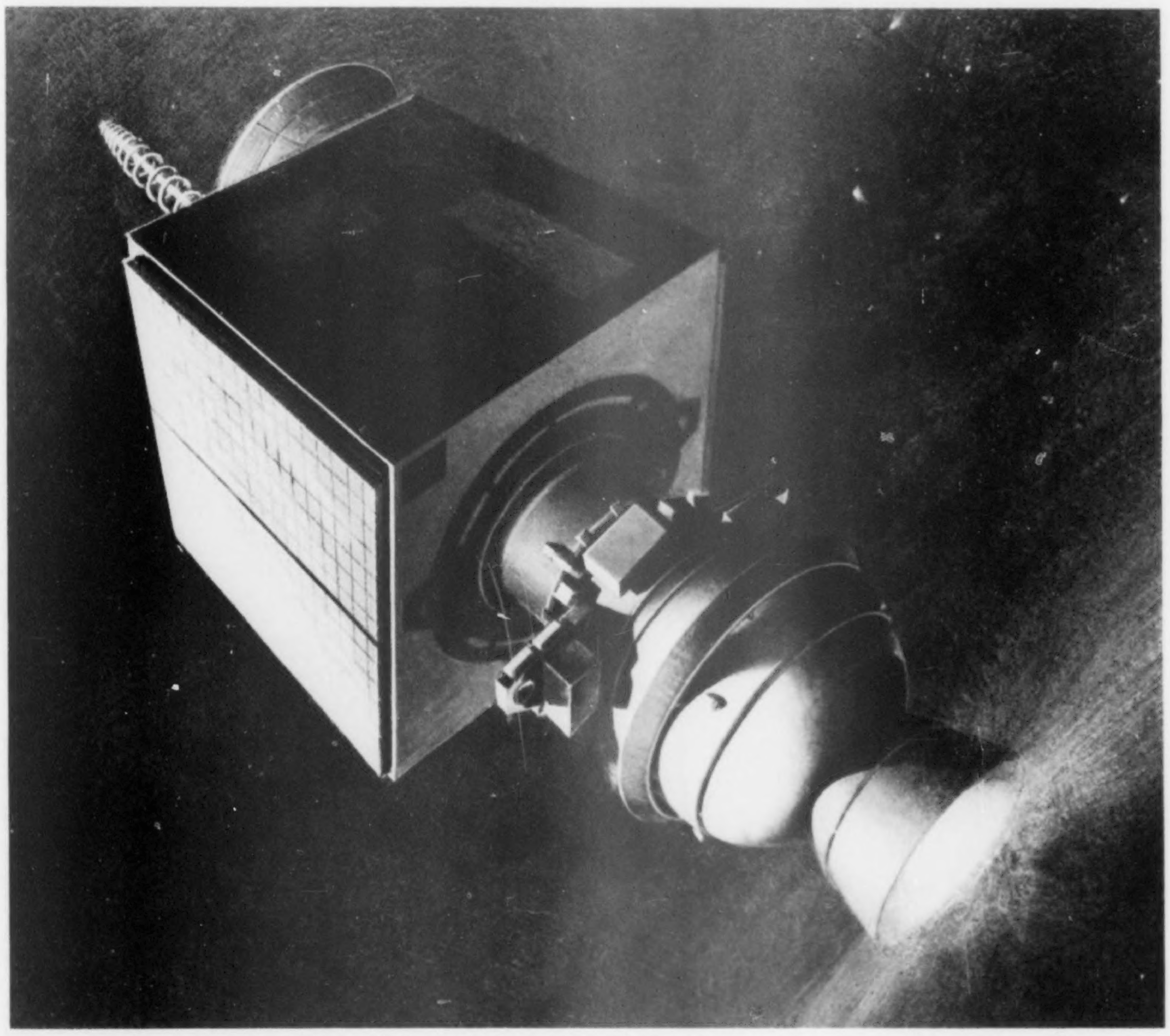
This house was designed in 1536 to be fastened to the top of a rocket and fired into space. Its purpose is unknown, but it appears to be one of the first ideas for a manned flying vehicle. The illustration is from the 1529 manuscript of Conrad Haas of Rumania.



Firework rockets, including modern looking delta wing and multi-stage rockets, are illustrated along with the manufacturing tools and a launching device in Francois Frezier's Traite des Feux d'Artifice *[Treatise of Fireworks] (Paris, 1747).*



The first successful 2-step liquid-fuel rocket (a V-2 and a WAC-Corporal) is pictured making its record-breaking high altitude flight of 392 km (244 mi.) from White Sands, New Mexico, February 24, 1949.



This artist's concept of a Payload Assist Module (PAM) will be used as an upper stage to the low Earth-orbiting Shuttle to boost a satellite or space probe into a higher orbit.

The other, Konstantin E. Tsiolkovsky of the USSR, produced in 1929 a special study of the subject, titled *Raketnye poyezda (Rocket Trains).* He likened the steps of a rocket to the cars of a train in which the main engine pulled the whole load. But there the similarity ended. In a rocket train each of the steps or cars has its own engine and performs independently when separated.

Unfortunately, the first large-scale step rocket was fired for war, not for peaceful exploration of space. During World War II, the Germans briefly used the *Rheinbote (Rhine Messenger),* an awkward-looking and inefficient 4-step solid-propellant surface-to-surface missile 11 m (37 ft.), weighing 1711 kgs (3773 lbs.) yet delivering a warhead of only 40 kgs (88 lbs.).

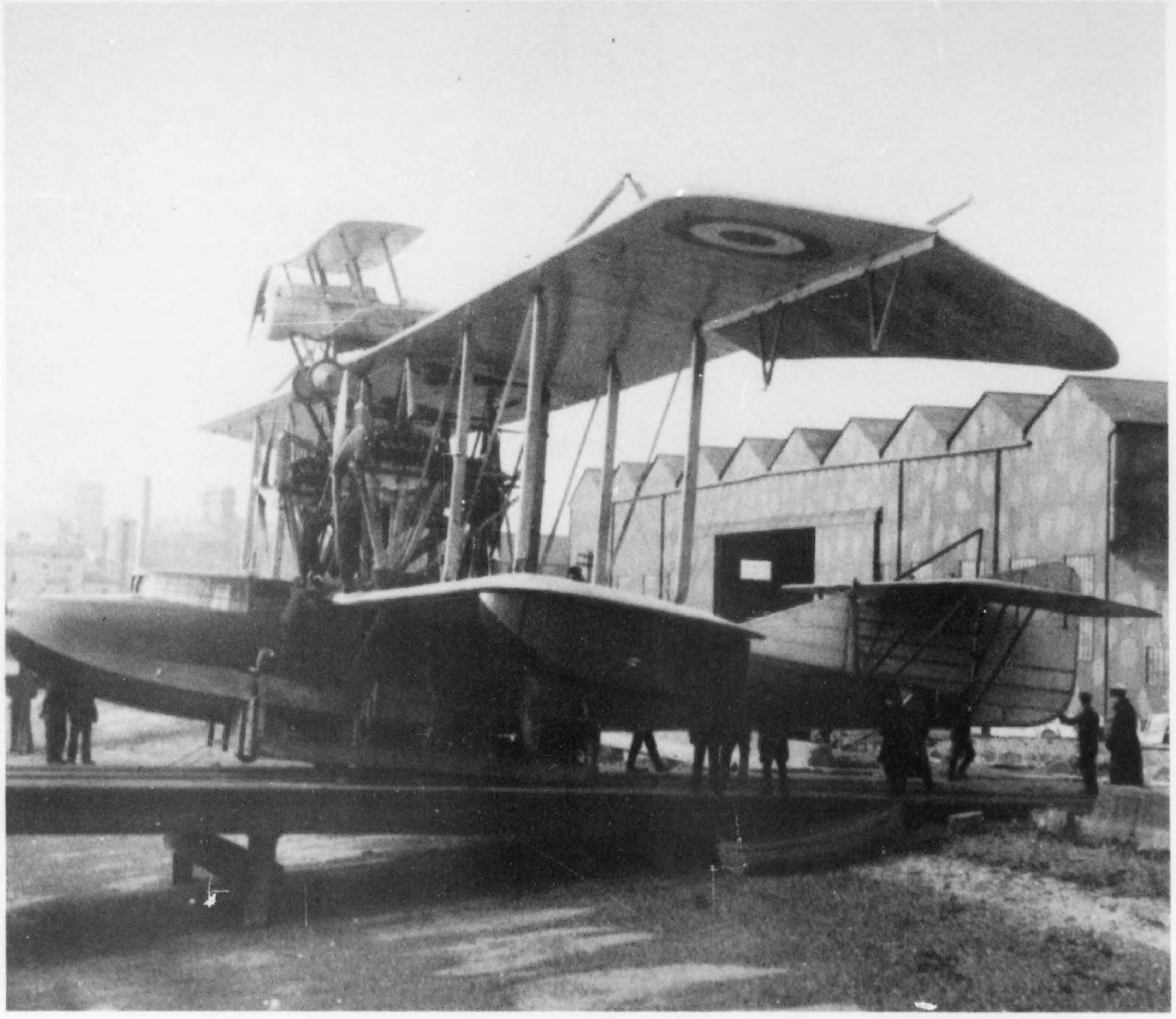
Although plans were on the drawing board for a 2-stage version of the far more deadly V-2 liquid-fuel rocket, this intercontinental manned bombardment weapon never materialized. However, a peacetime 2-stage version of the V-2 was built by the United States. Following the war the United States adapted several captured V-2s as high altitude research tools. On February 24, 1949, one of these reconditioned V-2s with a smaller American WAC-Corporal rocket on top of it, became the first successful 2-step liquid-fuel rocket when it reached the then unprecedented altitude of 392 km (244 mi.). The altitude stood as a record until 1957, the year the space age began.

With the launch of Sputnik 1 by a modified 3-stage Soviet Intercontinental Ballistic Missile (ICBM), the principle of the multistage rocket for space exploration as propounded decades earlier was proven correct.

Even the Space Shuttle is a form of a step rocket, although the two giant strap-on solid-fuel boosters burn at the same time as the Shuttle's main engine during the launch. Technically, this makes the Shuttle a stage-and-a-half vehicle, because step rockets work by successive stages being fired. The Shuttle is a low Earth-orbiting vehicle. If it is to be used to launch a satellite or space probe above its maximum operating ceiling of 1110 km (690 mi.), an additional rocket called either the Inertial Upper Stage (IUS) or the Payload Assist Module (PAM) must be attached to the satellite to boost it to a higher orbit. The difference between the two rocket motors (PAM and IUS) is payload lift capability. The IUS can lift heavier weights and for this purpose it is itself a two-stage rocket!

Next July 4, Independence Day, when the sky is lit with spectacular fireworks, remember that some of the earliest ones were the first step rockets, and in less than 500 years the same principles of rocketry are now carrying man into space. ■

Piggyback Aircraft



A Bristol Scout C is pictured on top of the seaplane Porte Baby at Felixstowe, England, 1916. The first successful flight of a piggyback aircraft was made in May 1916, by this British fighter-seaplane combination.

Kathleen L. Brooks-Pazmany
Research Assistant
Department of Aeronautics, NASM

On August 12, 1977, a Boeing 747 began rolling down the runway of NASA's Dryden Flight Research Center, California. This was no ordinary 747, nor was this an ordinary flight. The Boeing taxiing for takeoff was the Shuttle Carrier Aircraft (SCA) with the Orbiter *Enterprise* perched on top. Comdr. Fred Haise and Pilot Gordon Fullerton would attempt to make the first separation of the SCA/Orbiter.

Would the SCA be able to carry the Orbiter to altitude for release? Would the separation be successful? Would the Orbiter perform well as an aircraft and land as anticipated? Would the SCA land safely? If the Orbiter should fail to release properly, a dangerous situation could develop.

The culmination of years of planning, months of taxi tests, and unmanned, then manned, test flights ended without a hitch. The SCA/Orbiter successfully separated at 7345 m (24,000 ft.). Where did this idea of one aircraft carrying another piggyback originate?

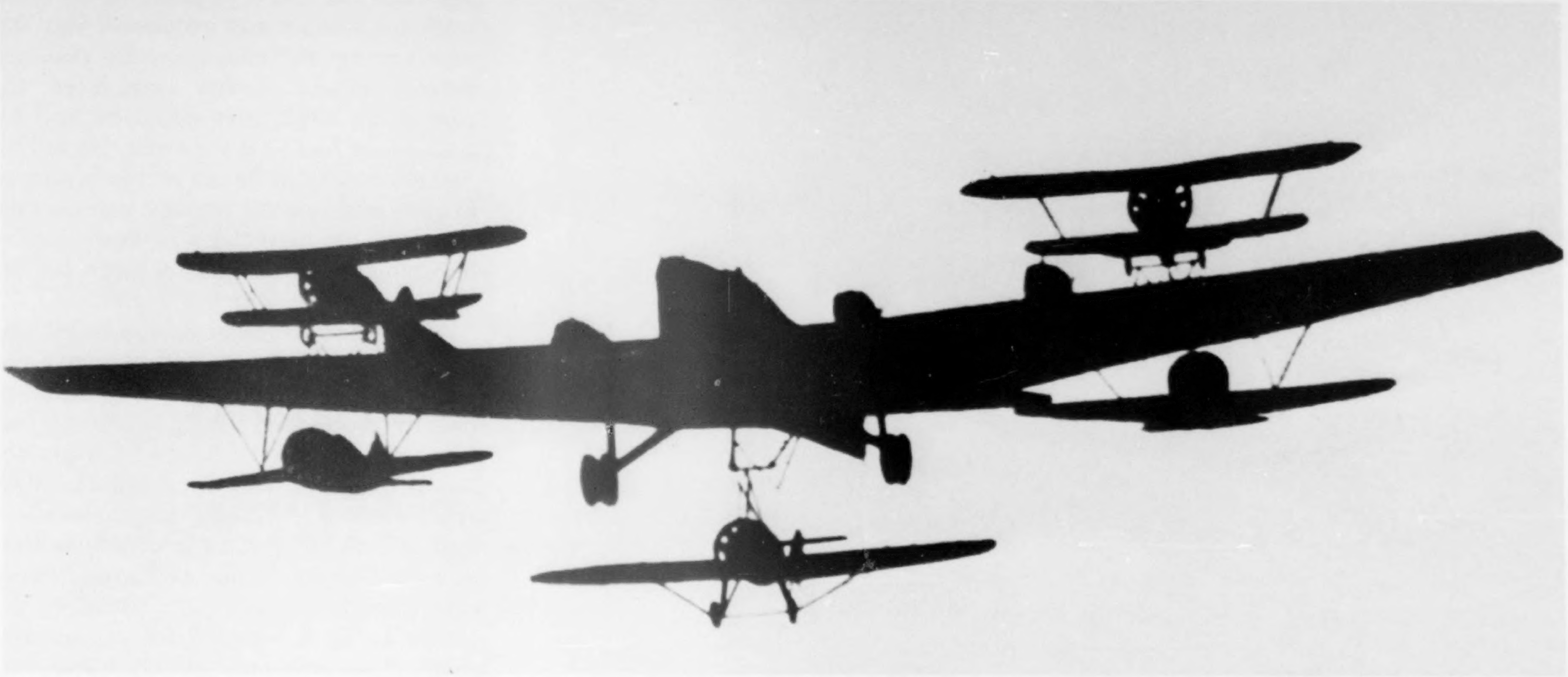
The first successful flight of a piggyback aircraft can be traced to 1916 at the Royal Naval Air Station, Felixstowe, England. Europe was embroiled in World War I. British ships and seaplanes patrolled for German submarines, and the Germans developed a seaplane fighter to use against them. German planes based at Zeebrugge on the Belgian coast patrolled the water between there and the North Hinder Lightship. The lightship was out of range for British land-based fighters, so British seaplane bombers were left with no defense against the speedy German fighters. This situation prompted the British Navy to mount a fighter on top of a seaplane as proposed by Comdr. John Cyril Porte. If the seaplane was attacked, the fighter could be released, and each would be capable of returning home.

The upper wing of a Porte E-X-1 was modified so that the wheels of a Bristol Scout C would rest in slots and be held in place by chocks. To separate the two, the Bristol pilot would start his engine, pull the chock release cable, and push the throttle forward to takeoff. On the first attempt one wheel of the fighter jammed, but Porte, at the controls of the seaplane, was able to bring the piggyback aircraft down. The release problem was solved by letting the fighter's wheel hang over the leading edge of the seaplane's upper wing. The fighter was held in place with a tail cable. The second separation attempt in late May 1916 was a success, but the program was not developed further.

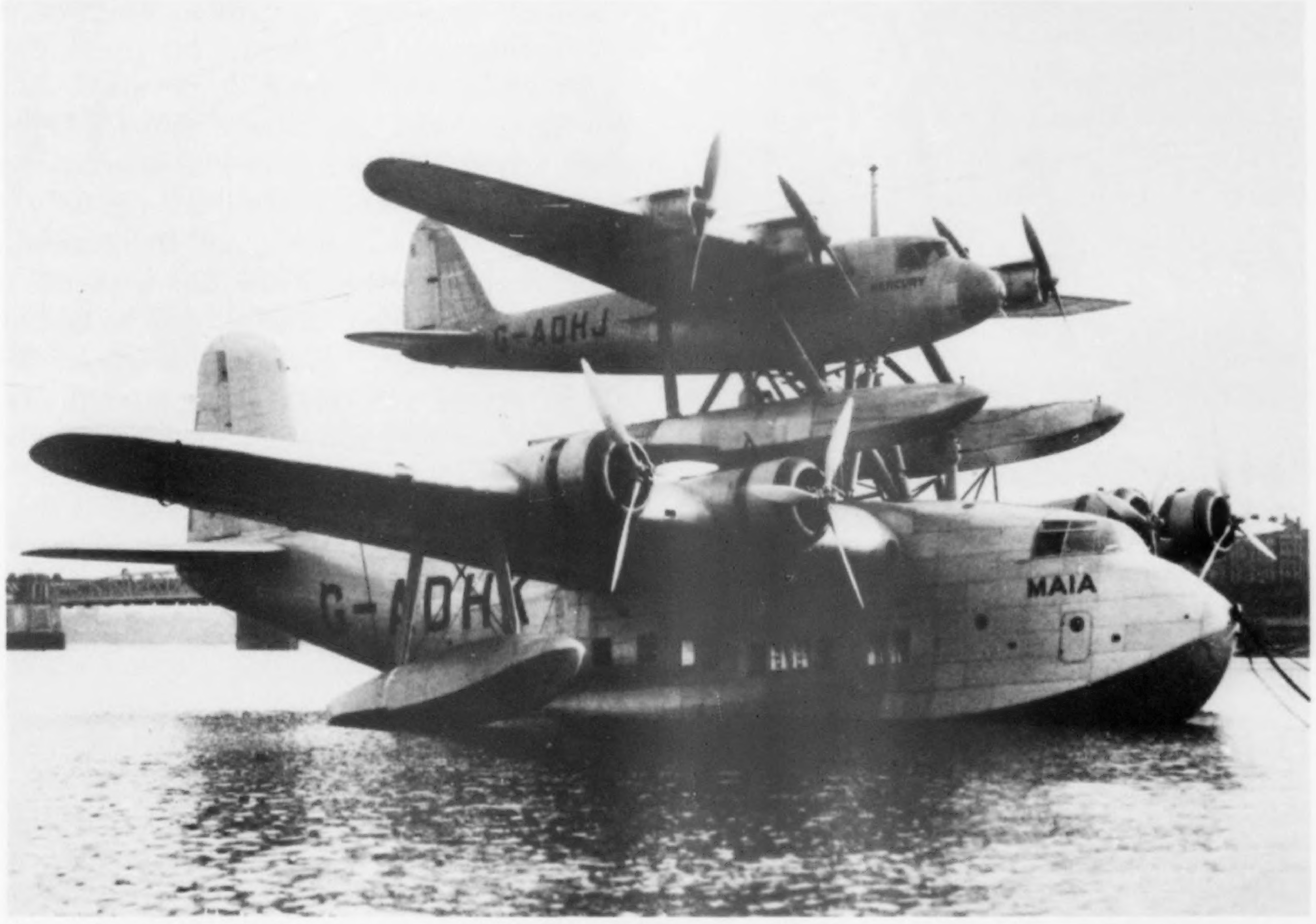
It wasn't until the early 1930s that another series of piggyback flights was made. The Russians were concerned with providing fighter escort for the entire length of their bomber's missions. Their fighters did not have the range to do this; but it could be achieved by having bombers carrying the fighters. The first successful flight was on December 3, 1931, when a TB-1 bomber took off with two I-4 fighters mounted on its wings. The most elaborate of the Russian Combinations, as they were called, consisted of a TB-3 bomber with two I-5s on the wings, two I-16s under the wings, and one I-Z under the fuselage These experiments lasted ten years, until the Russians realized that the program was impractical. There was not adequate time to train pilots to fly the combinations, and developments in military aircraft had made the piggyback idea obsolete.

In the mid-1930s, Maj. Robert Mayo proposed that Great Britain develop piggyback aircraft to extend the range of their airmail planes. These planes, carrying a maximum load of fuel and cargo, could be carried on top of a larger, lightly loaded aircraft. With assisted takeoff, the airmail plane could save enough fuel to significantly increase its range. Upon separation the carrier aircraft could return to home base where it could be fitted with another airmail plane or be converted to passenger service.

In support of this plan, the British Air Ministry agreed to subsidize Imperial Airways to run the long range airmail service and contracted with Short Bros., Ltd. to design both aircraft as seaplanes. The design of the lower component, or carrier aircraft, *Maia,* was adapted from the Empire flying boats. The upper component, or airmail plane *Mercury,* a twin-float, mid-wing seaplane was designed and built for the proj-



With all nine engines running, this awesome Russian TB–3 combination circled the airfield before releasing its five aircraft. The most elaborate of the Russian Combinations is pictured, consisting of a TB–3 bomber with two I–5s on the wings, two I–16s under the wings, and one I–Z under the fuselage. In the early 1930s the Russians experimented with piggyback flights to provide fighter escort for the entire length of their bomber's missions. These experiments lasted ten years until the Russians realized that the program was impractical.



Short-Mayo Composite at anchor, Kent, England, 1938. The lower component, or aircraft carrier, named Maia, *was adapted from the Empire flying boats. The upper component, or airmail plane, called* Mercury, *was designed for the project. Both aircraft were designed by Short Bros., Ltd., as seaplanes.*

ect. The Short-Mayo Composite performed as a single craft, the controls of the upper component being locked until separation.

The first separation test flight was made on February 6, 1938, followed by a series of tests. On July 21, 1938, after months of test flights, *Mercury* was launched from *Maia* over Foynes, Ireland, on its way nonstop to Montreal, Canada, carrying a full load of mail and newspapers. Demonstation mail flights were so successful that Imperial contemplated ordering a small fleet of the landplane version of the *Mercury* to use only for mail service. The Air Ministry did not agree with this idea because they believed that if separate passenger and mail services were created, neither would make enough money. The project ended because Great Britain entered World War II in 1939 and the aircraft were needed for other missions. *Mercury* was requisitioned by the military in June 1940, used as a trainer, and finally broken up in late 1941. "Maia" was used as a passenger aircraft and was destroyed May 11, 1941, during a bombing raid on Poole Harbor, England.

The 1940s German Mistel (Mistletoe) piggyback program began as a way to provide bombers with a fighter escort that could be released and recoupled in flight. This plan did not succeed, but a series of related experiments was initiated to study air-towing loads on attached aircraft and to investigate using a bomber-fighter piggyback in an attack role.

The bomber was extensively modified to carry the fighter on top. These necessary measures included: the installation of attachment points, additional fuel tanks, and new engines; rewiring to accommodate a new control system that connected to the fighter; and replacing the nose section with a warhead.

In previous programs each aircraft in the piggyback could function in concert or independently. In this case, the aircraft took off and flew to its destination with the bomber's controls operated by the pilot in the fighter. When the pilot was ready to disengage, he switched over the controls to the fighter. The bomber, armed with its warhead, was jettisoned as a bomb. The fighter was then refitted with another bomber.

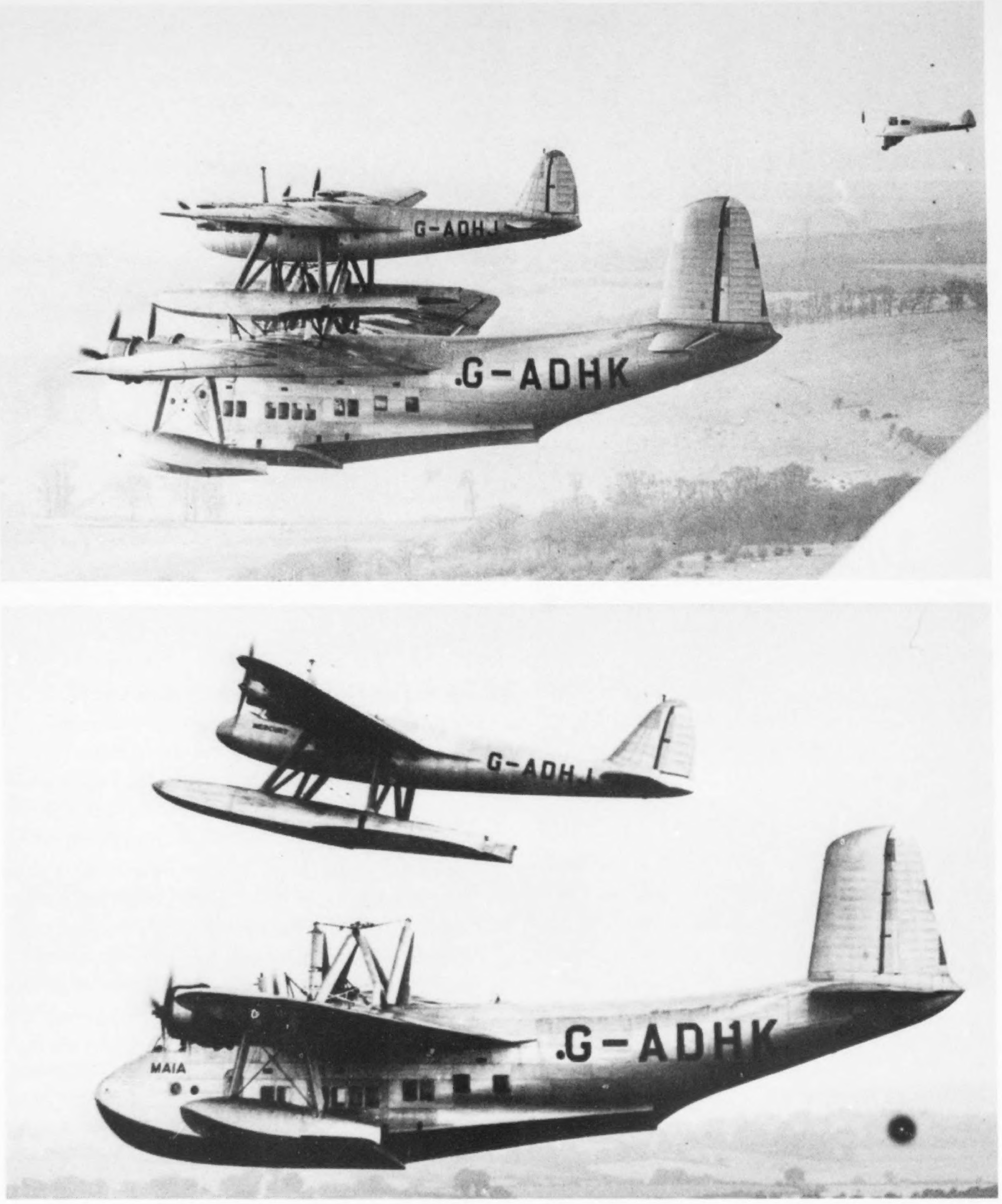
Different aircraft were used in this program, although the most widely used piggyback was the Junkers Ju–88/Focke Wulf Fw.190. This combination was used principally in bombing raids on bridges. Other piggyback aircraft were designed for reconnaissance and research.

The piggyback aircraft had been used in military and commercial programs. In the late 1940s its use as a research vehicle was found.

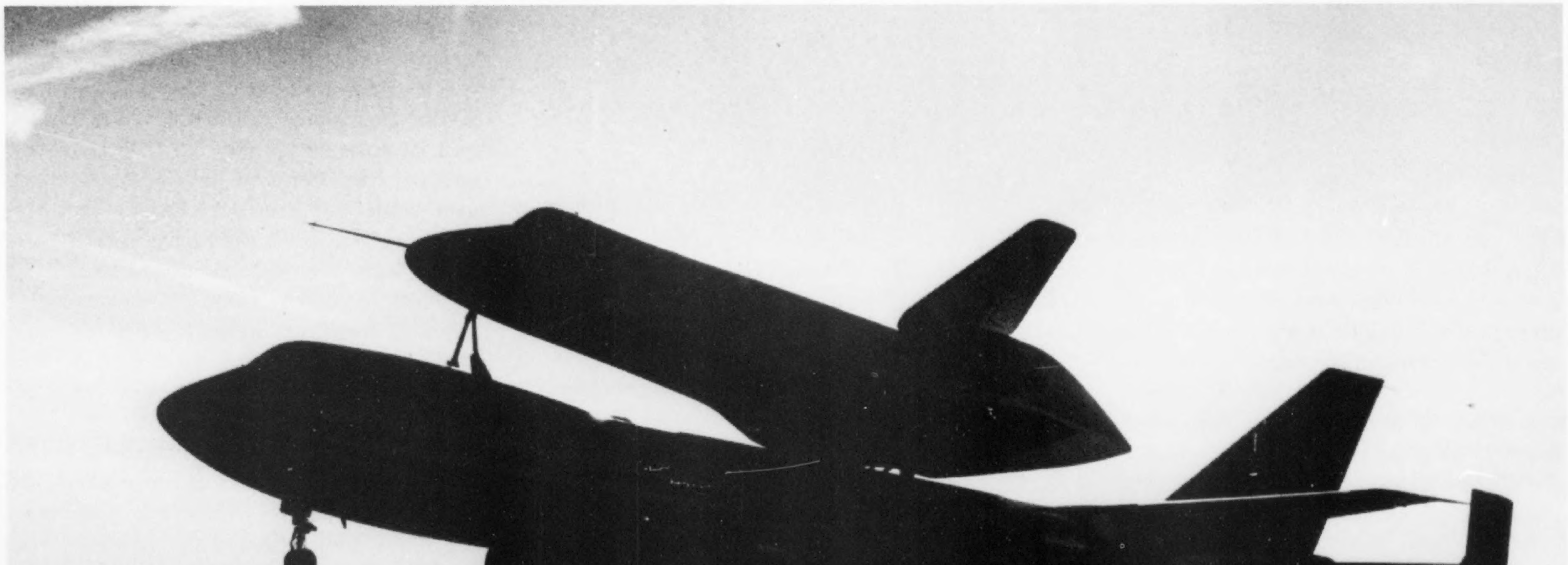
René Leduc began his work on ramjets in Paris, France, in 1933. By 1937, a design for the O.10 airplane to be fitted with his ramjet was proposed. But war was raging in Europe, so his research slowed down. Leduc completed the ramjet by 1940, just when he and his colleagues had to leave Paris. He hid his research data in barns in the south of France and waited for the war to end. Some of his material was destroyed in bombings, and he had to begin his research again.

The one problem Leduc faced was inducing enough air velocity into the ramjet's tube to ignite it. He resolved this by mounting the O.10 ramjet airplane on a modified SE-161 Languedoc for in-flight launch. On April 21, 1949, after a series of glider tests, the O.10 was successfully launched for its first powered flight. Leduc continued using this piggyback approach through the 1950s as he developed his ramjet aircraft. The program ended when the French government withdrew financial backing.

From the birth of the piggyback in 1916 to its application to the U.S. space program, piggyback aircraft have continued to adapt to advancements in technology. After almost 20 years, piggyback aircraft have come back into style. Initially, the Space Shuttle Orbiter, which performs as a glider in Earth's atmosphere, was carried on top of the Boeing 747 so that it could be launched for flight testing. Now the Orbiter is transported from landing site to launch site piggyback. This application to the U.S. space program is a useful and important role for the piggyback in the 20th Century. ■



Separation of the Short-Mayo Composite over Foynes, Ireland, on July 21, 1938, at the start of the Mercury's *nonstop flight to Montreal, Canada.*



The modified Boeing 747 takes the 68,040 kg (150,000 lb.) Shuttle craft for its 4th and next to last inert phase of NASA's Approach and Landing Test (ALT).

Shuttle Carrier Aircraft

Astronaut Gordon C. Fullerton (left), a flight crew member for the Shuttle Approach and Landing Tests (ALT), and Jere B. Cobb, Johnson Space Center flight operations pilot, are at the controls of a KC-135 zero-g aircraft as part of the 1976 ALT training. The ALT program was an important step in the process of preparing for the first spaceflight by a Shuttle Orbiter.

Gregory Kennedy
Museum Specialist
Department of Space Science and Exploration, NASM

How would you move the Space Shuttle Orbiter from the factory in California to the launch site in Florida? Remember—the Orbiter is powered only during ascent. NASA engineers decided to carry the Orbiter, which is roughly the size of a DC-9 jet liner, piggyback on a Boeing 747 Jumbo Jet.

NASA purchased a Boeing 747-100 from American Airlines on June 17, 1974. This passenger aircraft had to be heavily modified to fulfill its new role. Passenger seats and accommodations were removed; additional bulkheads and stiffeners were added to the fuselage; the engines were replaced with higher thrust JT 9D-7AHW units. The trim system was modified to permit two degrees more nose-down trim, and tip fins were added to the horizontal stabilizers to improve handling when the Orbiter was on top of the aircraft. Supports for the Orbiter were placed on the 747's back. Three support struts were added, one forward and two aft. They attached to the Orbiter by the same fittings used for the external tank. Finally, a bailout system was added. These modifications increased the basic weight of the aircraft by 1300 kg (2800 lbs.).

On September 17, 1976, *Enterprise*, the first Orbiter, rolled out of the Rockwell International assembly plant in Palmdale, California. *Enterprise* was not built to fly in space. Instead, it was used to test the low-speed flying and landing aerodynamic characteristics of the Orbiter. To accomplish these tasks, plans were made to carry *Enterprise* on top of the 747 Shuttle Carrier Aircraft (SCA) and to release it to make an unpowered approach and landing. This was the Approach and Landing Test (ALT) program—an important step in the process of preparing for the first spaceflight by a Shuttle Orbiter.

After its rollout in Palmdale, engineers moved *Enterprise* to the Dryden Flight Research Center, California, 58 km (36 mi.) away. *Enterprise* made this journey on a trailer on the ground.

The landing-test program was designed to proceed in a deliberate manner. The 747 arrived at Dryden on January 14, 1977. Several weeks later, on February 7, *Enterprise* was placed on its back. The aft end of the Shuttle was covered with a special tail cone, or fairing, to reduce aerodynamic drag and turbulence. A total of 13 flights were made during the program. Eight flights were captive, that is, the Orbiter remained attached to the 747 throughout the flights, and five were free flights where the *Enterprise* was released. Before any of these flights, there were ground vibration and taxi tests to verify the 747/Orbiter combination's control characteristics.

The first flight of this hybrid vehicle occurred on February 18, 1977. There was no crew aboard *Enterprise* during this captive flight, which lasted just over two hours. Four more so-called inert-captive flights were made to assess the handling characteristics of the mated craft. Next came three active-captive flights. For these flights, there were two people aboard *Enterprise*.

Finally, the first Orbiter free flight was ready. Apollo 13 veteran Fred Haise was in command; Gordon Fullerton was the pilot. (Fullerton would later be selected as the pilot for the third Shuttle space mission.) On the morning of August 12, 1977, Haise and Fullerton boarded *Enterprise*. The 747 taxied down the runway and took off, just as it had during the captive flights. All systems aboard *Enterprise* were go. The aircraft began a shallow dive, called pushover, and, at an altitude of 7350 m (24,100 ft.), *Enterprise* separated from the 747. Haise and Fullerton found that the craft handled well as they pulled its nose up to practice their landing flare maneuver. Then they pitched *Enterprise*'s nose down, accelerated, and began the first of two 90 degree left turns. Following the second turn, they were aligned to land on Runway 17. Five minutes, twenty-one seconds after its release from the 747, *Enterprise* touched down on the dry lake bed.

A month later, *Enterprise* was ready for its next flight with Cmdr. Joe Engle and Pilot Richard Truly at the controls. (Engle and Truly later flew the second Shuttle space mission.) *Enterprise* began the solo part of its flight at an altitude of 8000 m (26,000 ft.). This flight differed from the first in that Engle and Truly performed both low- and high-speed maneuvers. In addition, the first left roll subjected the Orbiter to a 1.8-g force,

After completing its second successful mission into space, the STS–2 Orbiter Columbia *begins its return flight to the Kennedy Space Center aboard the Boeing 747 Shuttle Carrier Aircraft.*

duplicating the maneuver used during the return from space missions. Free flight #2 lasted 5 minutes, 28 seconds.

Haise and Fullerton were again at the controls for the third free flight on September 23, 1977. Again, the 747 did its job as carrier and launcher for the *Enterprise.* On this flight, Haise and Fullerton used an automatic system for the last part of their approach to Runway 17. The automatic system receives information from the microwave scan beam landing system and is used to guide Orbiters returning from space.

For the last two free flights, the tail cone was removed from *Enterprise.* Dummy engines were added to the Orbiter to duplicate the aerodynamics of a Shuttle when it returns from space. Without the tail cone, the airflow from the Orbiter's aft end was very turbulent, as indicated by the oscillations of the 747's horizontal stabilizers. *Enterprise* was released at an altitude of 6830 m (22,400 ft.). Because of the increased drag, the flight path was much steeper than on previous test flights—minus 18 to 24 degrees versus minus 10 to 14 degrees for the flights with the tail cone on. The steeper flight path also meant a shorter flight; free flight #4 lasted just over 2½ minutes.

One more landing test was made. On October 26, 1977, Haise and Fullerton landed *Enterprise* on Dryden Flight Research Center runway #4. This was the first Shuttle landing on a concrete runway. Free flight #5 lasted 2 minutes, 1 second.

Even though the approach and landing test flights were over, the 747 was still needed to transport Space Shuttle Orbiters. *Enterprise* was scheduled to be used in vibration tests at the Marshall Space Flight Center in Alabama. Later, during the summer of 1978, it was used at the Kennedy Space Center in Florida to verify how well all the Shuttle launch facilities fit with an actual vehicle.

The 747 would have to be used to move the Orbiter around the country. For such ferry flights, the front Shuttle support was lowered. During the landing test flights, *Enterprise* sat on top of the 747 with its nose pointing up at an angle of 6 degrees. An angle of only 3 degrees was desirable for longer cross-country flying to reduce drag.

The flight to Alabama was made without incident as was the subsequent trip to Florida. Finally, *Enterprise* was ferried back to the Dryden Flight Research Center and returned by overland transport to Rockwell's Palmdale plant. *Enterprise* was stripped of parts that could be used on later Orbiters, and it now sits in storage to be used in a few years to test the launch facilities at Vandenburg Air Force Base.

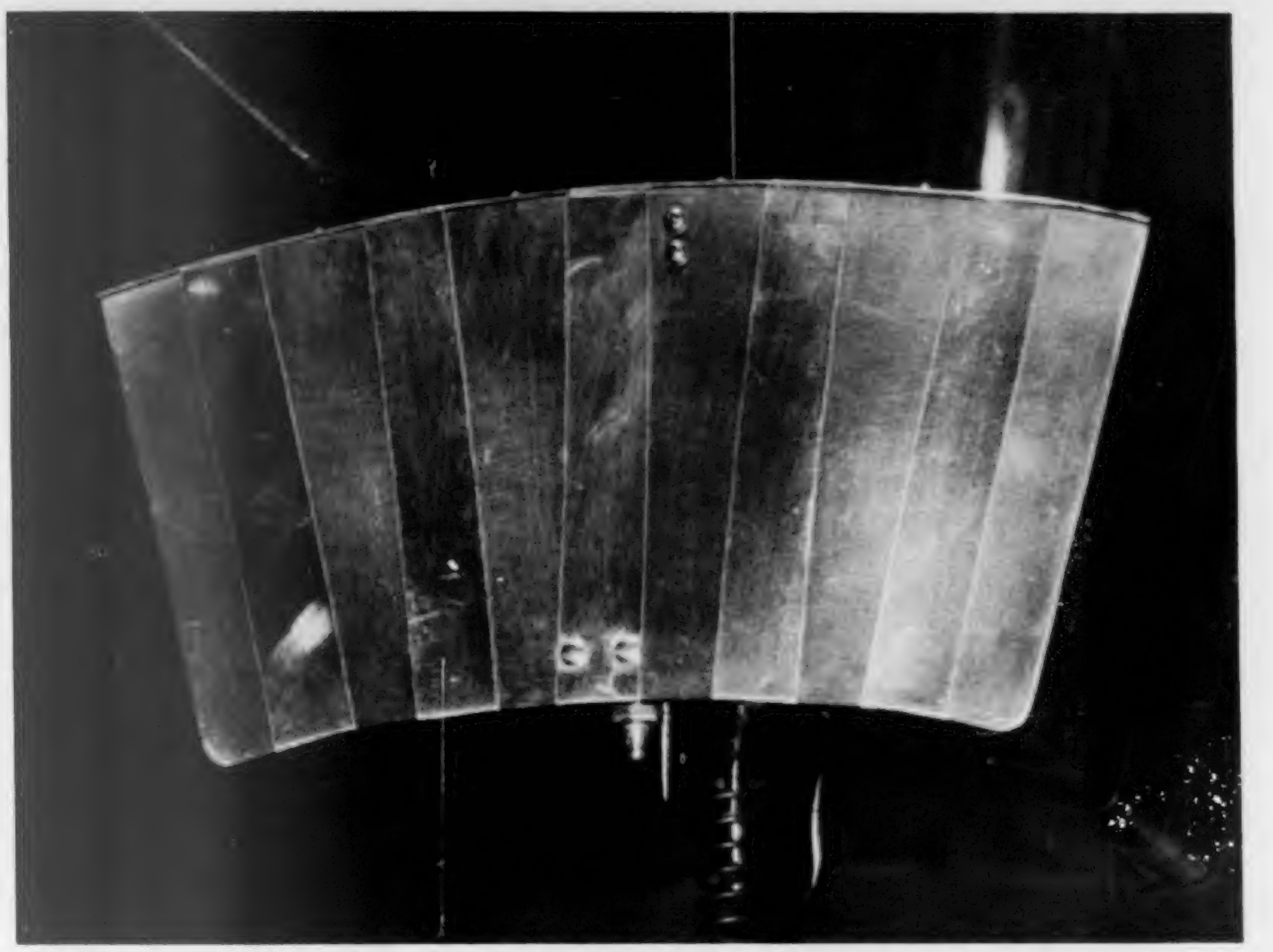
The 747, however, is still in use. On March 20, 1979, it took off from Dryden with the second Space Shuttle Orbiter, *Columbia,* on its back. Four days later, following stops in El Paso, San Antonio, and Eglin Air Force Base in Florida, *Columbia* arrived at the Kennedy Space Center.

Columbia's first four flights constitute a flight test program to explore the Shuttle's capabilities in space. Each of these flights concluded with a landing in the southwestern United States, requiring the 747 to carry the Shuttle back to the launch site in Florida.

In the near future, returning Shuttles will land at the launch site. This will reduce, but not eliminate the need for the 747 ferry. There may be occasions when the 747 will be needed to transport an Orbiter from the Kennedy Space Center to the west coast launch site at Vandenburg Air Force Base. Further, if a Shuttle should ever make an emergency landing at one of the back-up landing strips, the 747 will be needed to retrieve it. ■

OSCAR

Kerry M. Joëls
Curator
Department of Space Science and Exploration, NASM



OSCAR 1 was built for only $63.00 and in 1961 operated for almost 20 days. Over 5000 reception reports from 28 countries were received. This replica of OSCAR 1 is displayed in the Satellites Gallery, NASM.

Amateur radio operators (hams) are among the most active hobbyists and experimenters in the world, so it is not surprising that they wanted to use space for relaying signals very early in the space age. The use of piggyback satellite launches would be ideal since this group of enthusiasts could not afford the cost of a launch vehicle.

Only four years after Sputnik 1, a group of radio amateurs launched OSCAR 1 (Orbiting Satellites Carrying Amateur Radio). This was also the world's first non-governmental satellite. Hams who had been among the first to detect Sputnik's radio beacon were now tracking OSCAR 1 as it sent the word "Hi" in Morse code. The little spacecraft was built by a team of California "hams" for the astonishing cost of only $63.00. The piggyback launch on December 12, 1961, cost them nothing.

OSCAR 1 operated for almost 20 days, and over 5000 reception reports from 28 countries were received. On June 2, 1962, OSCAR 2 was piggybacked into space and also produced hundreds of reception reports. The amateurs were now ready to try "active" satellite communication.

The OSCARs are launched into polar orbit, making passes from north to south and are generally 805 km (500 mi.) high. The higher the orbit, the more time the satellite is visible to any given point on the ground. Commerical Communications Satellites are placed in a 35,900-km (22,300-mi.) orbit over the equator. In this location, they circle the Earth once in 24 hours and so appear motionless in the sky. This is called geostationary orbit. Polar orbit is reachable with a piggyback launch, however, so OSCARs continue to use these orbits.

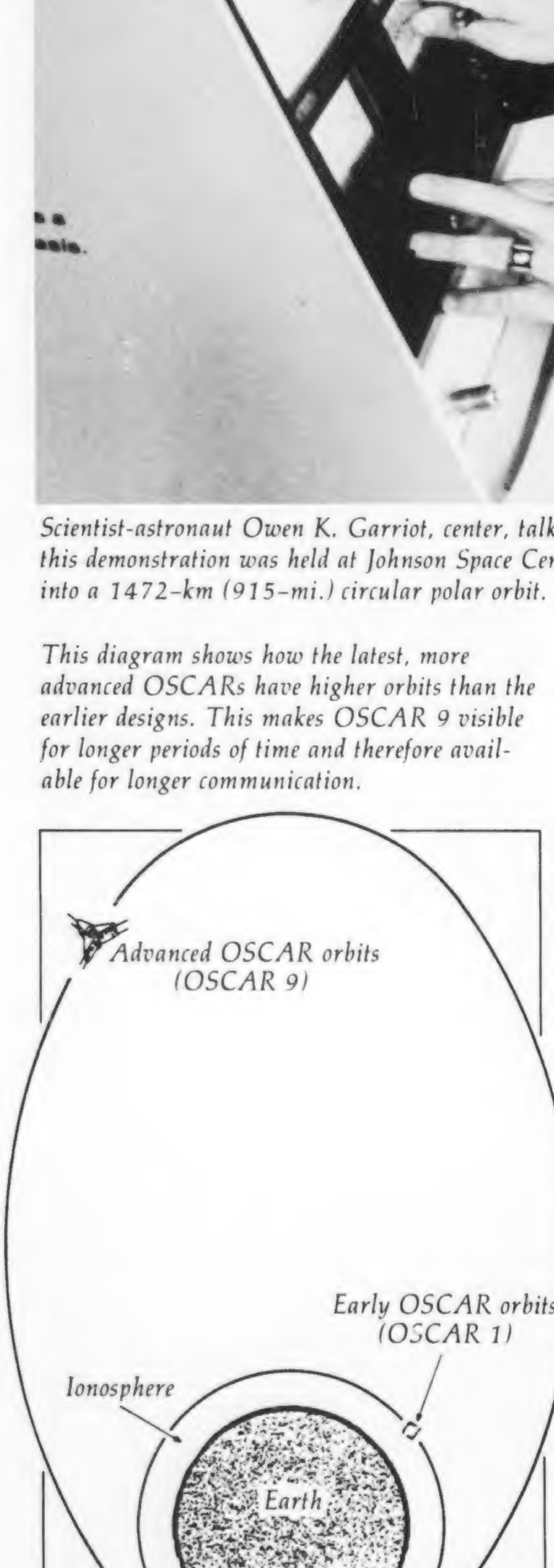
Right: Kennedy Space Center's OSCAR antenna is a typical antenna used to communicate with OSCAR. OSCAR uses standard ham radio frequencies and is available to amateur radio operators around the world.

OSCAR 3 actually beat *Early Bird*, Intelsat I, the first commercial communication satellite, into service. The amateurs now had their own satellite that could receive and retransmit signals, permitting conversations via space. But they didn't stop there. OSCARs have since become more sophisticated. OSCAR 4, which carried the first U.S.-USSR amateur satellite contact, used a repeater that could utilize two frequency bands at once. The amateurs were now entering "big-time" technology. During this period, the Radio Amateur Satellite Corporation (AMSAT), a miniature version of INTELSAT, was founded to organize the OSCAR program. Then, on January 23, 1970, OSCAR 5 was launched. This was a test satellite designed and built by Australians. Even in a low-cost piggyback program, test and experimental spacecraft were required.

The new OSCARs were, in effect, miniature versions of their commercial big brothers. Instead of the 8000 km (5000 mi.) maximum range of the earlier spacecraft, the new generation of OSCARS provided 18,000-km (11,200-mi.) range—halfway around the Earth. They were more powerful and were in higher elliptical orbits. OSCAR 6, launched October 15, 1972, worked

Scientist-astronaut Owen K. Garriot, center, talked with operators in Florida, Texas, Mississippi, and Connecticut during a 19-minute pass when this demonstration was held at Johnson Space Center, Houston, Texas. OSCAR 9 was launched piggyback with other payloads in November 1974 into a 1472-km (915-mi.) circular polar orbit.

This diagram shows how the latest, more advanced OSCARs have higher orbits than the earlier designs. This makes OSCAR 9 visible for longer periods of time and therefore available for longer communication.



until mid-1977 and had a "transponder" (the receiver/repeater) like its commercial counterparts. OSCAR 7, with its 1460-km- (910-mi.-) high orbit, was similar. It was launched with a meteorological spacecraft, an Improved Tiros Operational Satellite (ITOS). The signals were remarkably clear, and even stations with the low power of walkie-talkies were actually able to use the satellite. OSCAR 8 rode into orbit with the Landsat-C Earth-sensing spacecraft. Landsat and various weather satellites use polar orbits for complete Earth coverage and so are logical OSCAR launch opportunities.

The latest OSCAR has progressed even further. OSCAR 9 rode piggyback with a Solar Mesosphere Explorer (SME) satellite on its Delta launch vehicle. Also called UOSAT (University of Surrey Satellites), this spacecraft was constructed in Great Britain and is the first in the OSCAR Series to transmit scientific data for reception by amateurs. It has a voice synthesizer that speaks with a 150 word vocabulary and gives information about the spacecraft and its experiments. It also has a camera that produces 777-sq km (300-sq. mi.) images of Earth from orbit. The "ham" can then display the picture on a standard TV set.

All of these activities can be used in the classroom, and in fact, educational demonstrations using OSCAR have been conducted for years. AMSAT and the American Radio Relay League (ARRL) have programs to bring the radio amateur, OSCAR, and classrooms together. Demonstrations are available almost everywhere by local amateur radio enthusiasts. The range of what can be taught is impressive: fundamentals of spaceflight such as orbits, launching, tracking; geography; communication concepts; basic science such as electricity, wave theory; mathematics; and even social studies.

OSCAR has, perhaps, the most direct benefit from piggyback launches, although other satellites are also launched that way. Most have been small scientific satellites, but with the era of the Shuttle, multiple or piggyback launches of large satellites will be common. ■

For additional OSCAR information, write: *Getting to know OSCAR from the Ground Up,* ARRL, 225 Main Street, Newington, CT 06111.
Using Satellites in the Classroom—A Guide for Science Educators, Martin Davidoff, NSF (out of print; check resource centers).

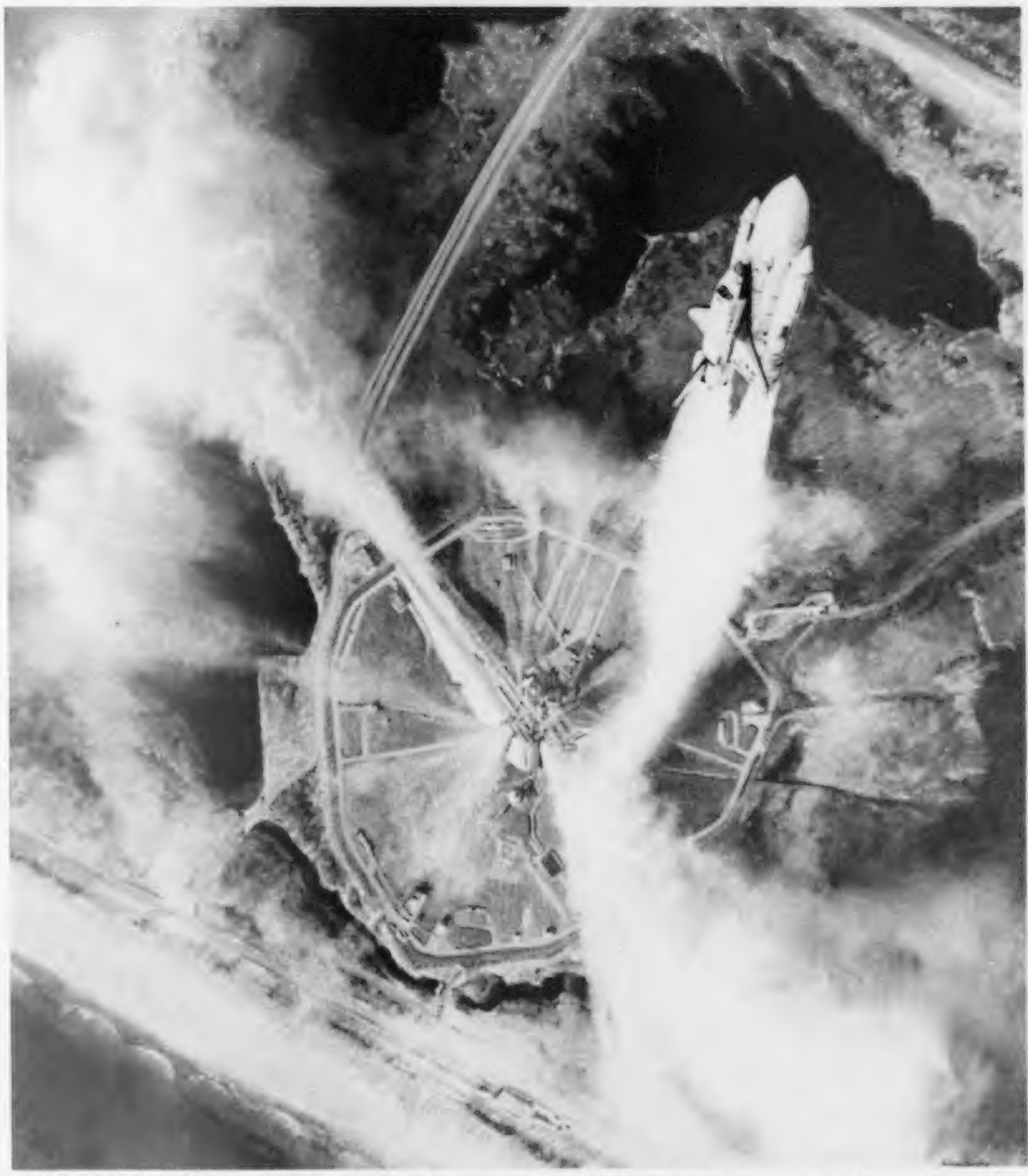
The Artist and the Space Shuttle

Robert Schulman
Graphics Coordinator
Public Affairs Division, NASA

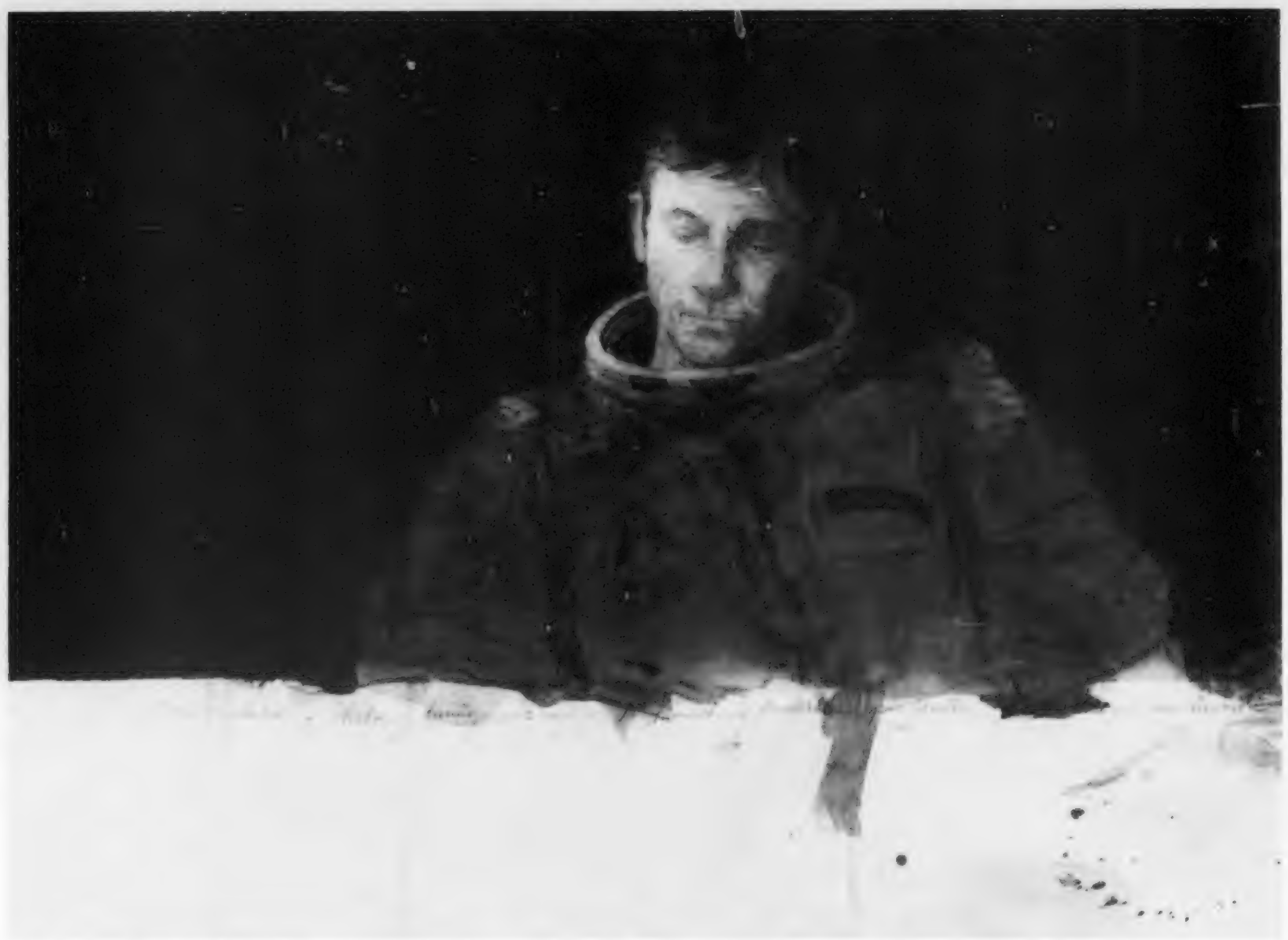
Artists have long played a significant role in the archival recording of our nation's important historical events. Since about 1964, NASA has been conducting an active art program to collect a history of mankind's exploration of space. Nationally known artists are invited to document NASA's major activities and render personal impressions of key events in the space program. Artists participating in this activity have ranged from traditionalists such as Peter Hurd and James Wyeth to modernists such as Robert Rauschenberg and Lamar Dodd. NASA made it possible for selected artists to be present at Cape Canaveral as astronauts suited-up for their flight and were launched into space, and artists were at Houston Mission Control during the Moon landing. Artists were aboard recovery ships when the astronauts returned to Earth from their long voyages and they have piloted Lunar Module simulators to make-believe moons. In short, NASA has tried to provide them every possible view and experience.

Artists recorded the events at Kennedy Space Center, Florida, for the first flight of the Space Shuttle *Columbia*, April 12, 1981. They came from all parts of the country and included such renowned names as Lamar Dodd, Wilson Hurley, Bob McCall, Tom O'Hara, Jack Perlmutter, Robert Rauschenberg, and Arthur Shilstone. Another team of artists also gathered on the dry lake bed in California's Mojave desert to record *Columbia*'s first landing. The enthusiasm expressed by these individuals for this assignment was only exceeded by the fascinating drawings and paintings that

Artist Wilson Hurley of Albuquerque, New Mexico, paints a preliminary oil study of Space Shuttle Columbia *on the pad at Kennedy Space Center, April 9, 1981.*



STS-1 Columbia Launch, *an oil painting by artist Wilson Hurley, presents a dramatic view of launch pad 39A and the* Columbia *on its first flight into space from the Kennedy Space Center, April 12, 1981.*



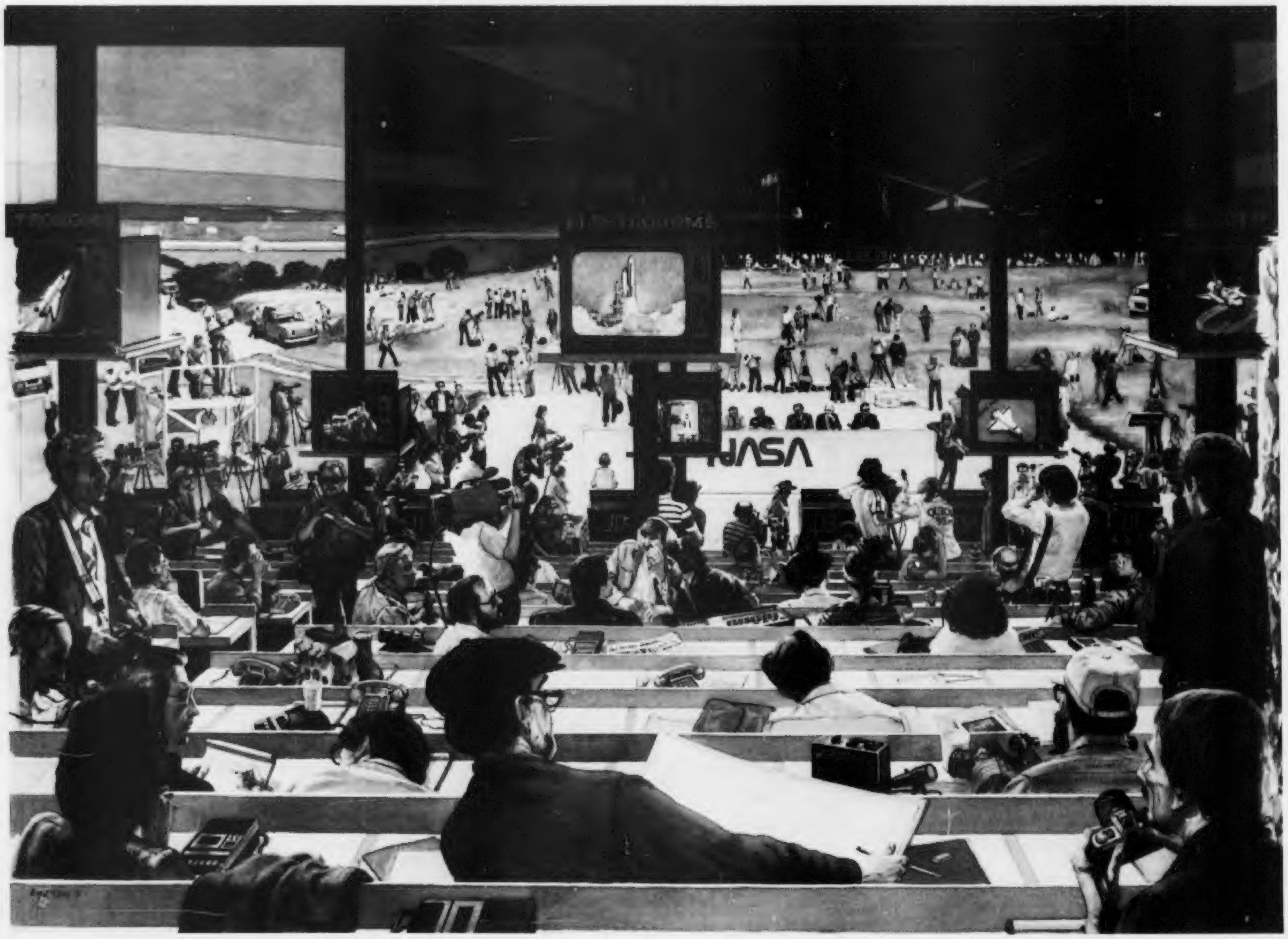
When Thoughts Turn Inward, *a watercolor painting by artist Henry Casselli, shows astronaut John Young during suitup for the first launch of America's Space Shuttle* Columbia, *Kennedy Space Center, April 12, 1981.*

Time, Space and Columbia, *a watercolor painting by artist Billy Morrow Jackson, shows the artist with sketch pad in hand sitting in the foreground of the picture as he surveys the panorama of shuttle activities on November 12, 1981, Kennedy Space Center. The TV monitors tell the entire story by showing the different phases of the mission all at one time.*

they produced. After the first Space Shuttle launch, Wilson Hurley said . . . "the Launch is the most exciting event I have witnessed in my life, and it will probably take me years to assimilate my feelings to where I can produce paintings that come close to the thrill it gave me."

The documentary art produced during this historic flight, along with many other drawings and paintings that portray the development of Space Shuttle since 1977, provide a unique, interpretive record of this country's new Space Transportation System (STS) and a new era in space. Along with documenting the space effort in every way possible, these paintings stand on their own as works of art.

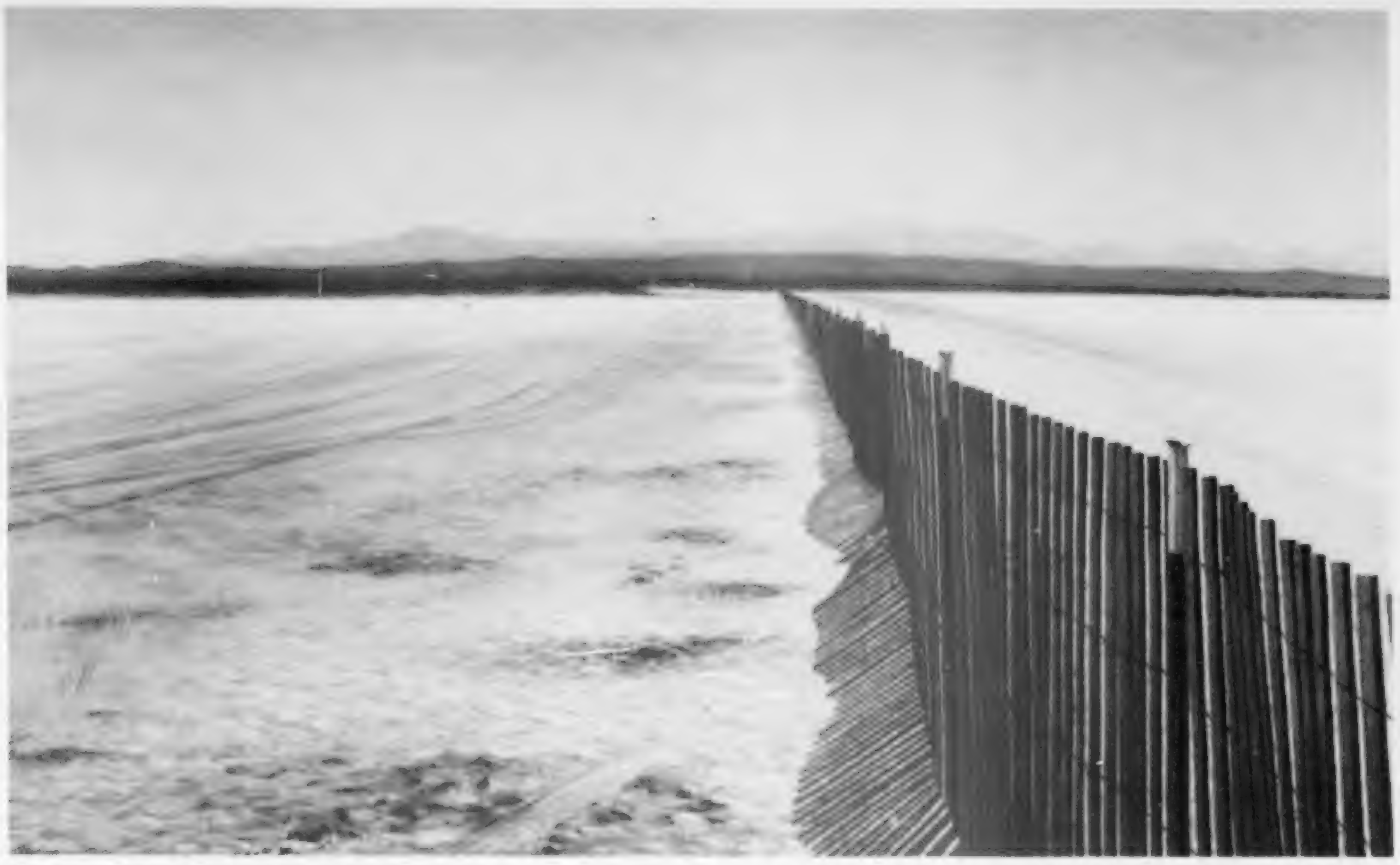
Many of the artists produced preliminary color studies or paintings on location; some worked directly on watercolor blocks; others worked in oils and acrylics using makeshift easels for support. The work environment is understandably hectic with the noises and movements of crowds of observers, cameramen, TV crews, and the press. Although the artwork produced for the Space Shuttle collection represents a wide range of techniques and styles from the very realistic approach to abstract images and impressions, the



"harmony" is obvious to those who have the privilege of viewing this fine work. Each painting depicts an intimate human record for future generations to view some very exciting moments of the Space Shuttle story as seen through the eyes of the artist.

Regardless of the approach, the quality of the paintings in NASA's collection, reflected by the use of color, light, texture, and composition, is indeed impressive. Dr. H. Lester Cooke, former curator of painting at the National Gallery of Art, Smithsonian Institution, guided the NASA Art Program during the Apollo moon launchings. He pointed out, "Painting is the most lasting of all visual records. Perhaps this project will help to prove that the United States produced in the sixties not only engineers and scientists capable of shaping the destiny of our age but also the artists worthy to keep them company."

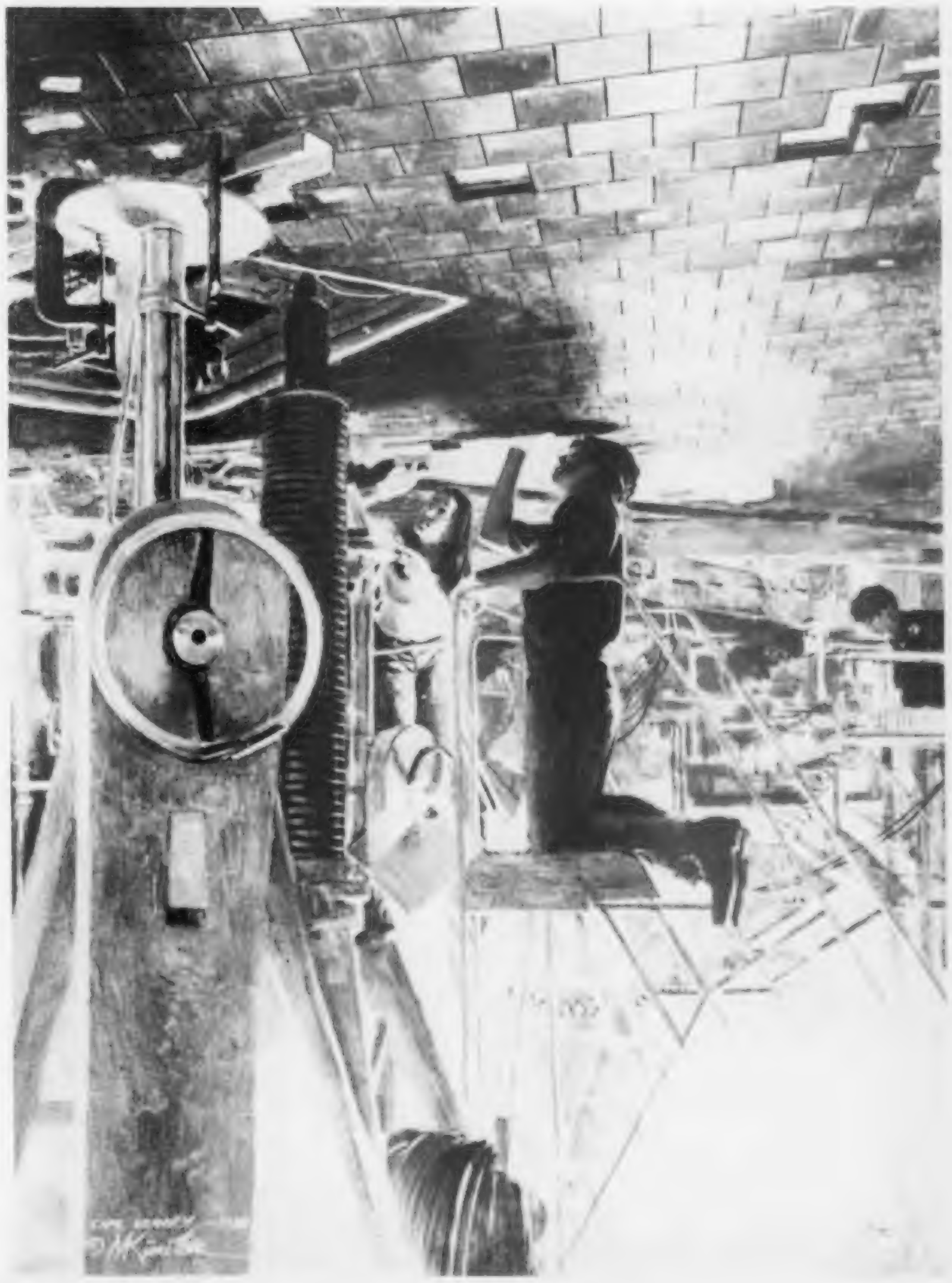
With today's new Space Shuttle art collection, the continuity of the collection's philosophy has not been lost. Its theme and thrust are as strong as in the beginning. The artist-on-the-spot captures the emotional impact and hidden significance of the activities of each Shuttle launch. They continue to give each major event yet another dimension by creating this documentary art. ■

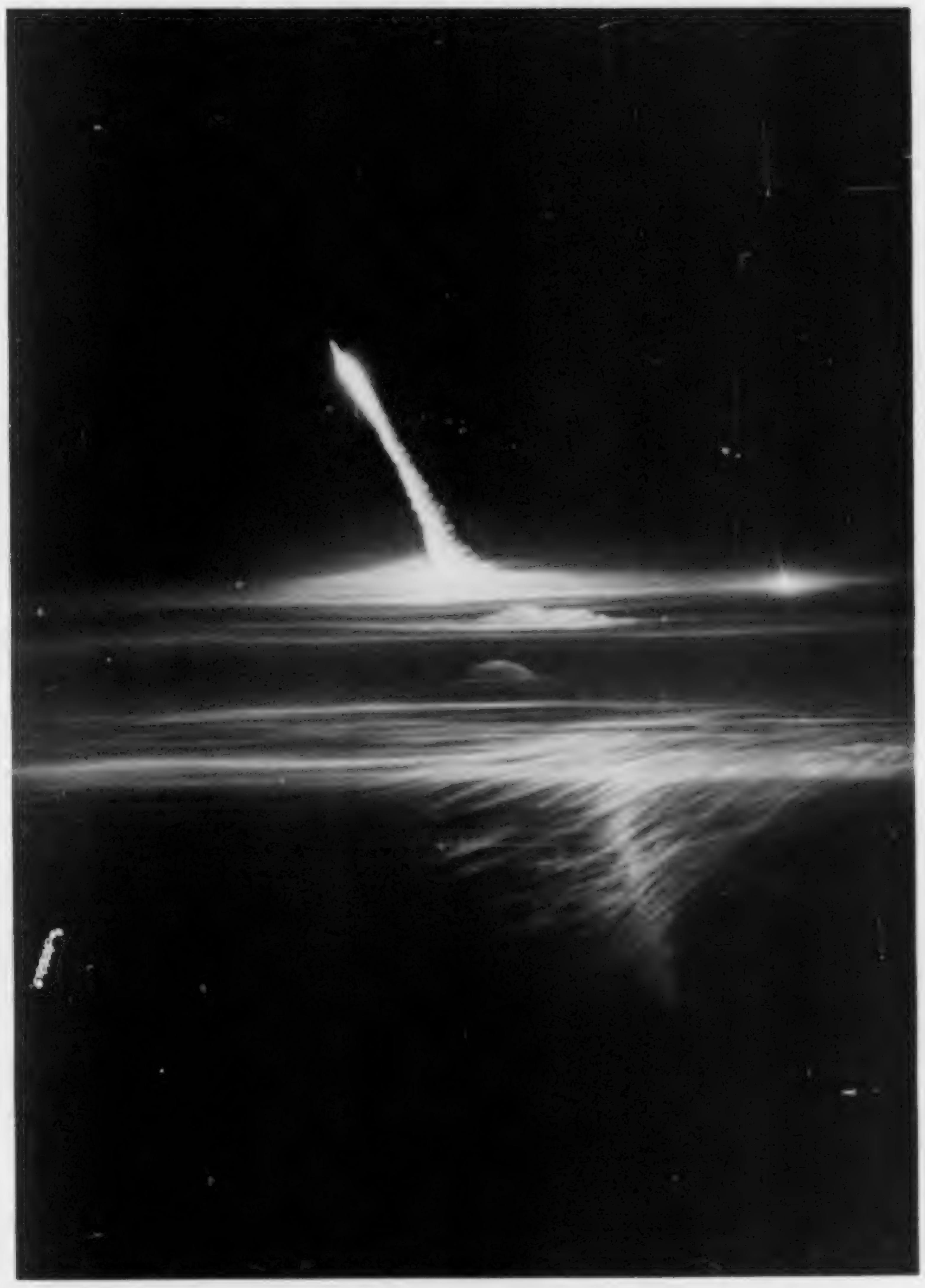


After Touchdown, *an oil painting by artist Robert Shulman, is the public viewing site the day after the second landing of the Space Shuttle* Columbia. *Sky, wind, heat, sand, and a temporary fence along with quickly disappearing footprints and tire tracks are all that remain of the thousands of spectators that witnessed the Columbia touchdown on the desert-dry lake bed at Dryden Flight Research Facility, November 14, 1981.*

Bottom left: Tile Team, *an oil painting by artist Morton Kunstler, shows the Orbiter Processing Facility, Kennedy Space Center, 1980.*

Bottom right: Columbia Launch Fantasy, *mixed media painting by artist Andreas Nottebohm, is the artist's interpretation of the first launch of the Space Shuttle* Columbia, *April 12, 1981, Kennedy Space Center.*





Counting Days and Years

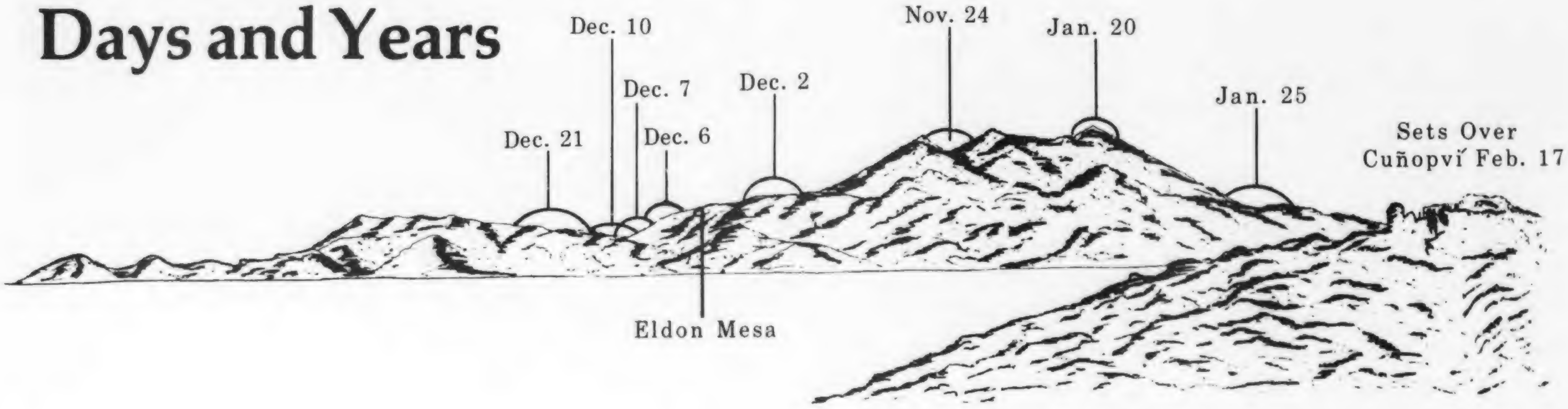


Fig. 1. Part of a Horizon Calendar—A simple and common method of composing a calendar is to determine either sunrise or sunset directions along a fixed horizon viewed from a set location. This example shows sunset directions over the San Francisco Peaks in northern Arizona, before and after the date of winter solstice (about Decemer 21), observed from a Sun Watcher's station at one of the Hopi Pueblos.

Von Del Chamberlain
Astronomer
Department of Space Science and Exploration, NASM

In the last issue of *Air & Space* we noted that the first observatories were simply places where people made naked-eye observations of the movements of celestial objects. These observations were generally made in order to establish useful calendars; the best object to observe being the Sun. It is surprisingly easy to make a calendar by observing the Sun. All that is required is a station with an unobstructed view of either the eastern or western horizon, along with lots of motivation, perseverance, and patience to go to the station regularly. The observations must be made from the same place, and the features of the distant horizon must be permanent.

Various cultures throughout the world have used such observations to derive horizon calendars, and they are still used by the Hopi and other Pueblo Indians of Southwest America. The Sun Priest goes daily to his observing place to watch the Sun rise or set. He knows that each year the Sun migrates in its rising and setting along the horizon, and that it is furthest north at mid-summer and furthest south at mid-winter. From experience he has memorized the relationships between special features of the horizon (rock outcrops, prominent pinnacles, and low places between two distant mountain slopes) and when the Sun reaches them. The tribe's important events have become associated with the features of the horizon, and it is the Priest's job to announce them when the Sun appears to stand on these features. Figure 1 is an example of part of a solar horizon calendar. It indicates dates and horizon features for sunset before and after the time of Soyal, one of the most important Hopi ceremonies that occurs about the time of the winter solstice.

In addition to making observations, people who used horizon calendars generally had a method of counting the days. This enabled them to check the system and to associate it with other things, such as the phases of the Moon, which provided a monthly calendar. The monthly calendar does not stay in phase with the annual one because there are not an even number of lunations (each about 29½ days long) in a year of 365 days. Some tribes, including the Hopi, used counting sticks to keep track of the days. Marks were cut into these sticks for each day, and special marks were cut for particularly important days. Sets of sticks from successive years could be compared in order to determine the number of days between important events. Sticks, used for particular years could have been associated with those years as "historic records" of the people's traditions.

Several Indian groups, including the Pima and Papago, used counting sticks to record the passage of years—calendar sticks. Some of these do not appear to be related to horizon calendars at all but rather were marked each year when a particular season arrived. This could be determined by earthly clues such as ripening of fruits, budding of trees, or any other recurrent phenomena. The sticks were marked at the proper time each year by someone in the group designated keeper of the calendar. They knew how to recognize the symbols cut into the sticks to recall the years and could remember various events that occurred in those years. Most of the events dealt with things important to the group, such as battles with enemies, deaths of important people, or disastrous weather resulting in hardships. Interesting natural phenomena were sometimes remembered by the year marks. The most outstanding example is the great Lenoid meteor shower of November 1833 (Figure 2).

The Dakota, or Sioux, Indians of the American Plains used a similar method for counting and keeping track of the years, but instead of sticks, they made markings on animal skins. These are referred to as "winter counts," because the year began with the first snow and ran through the spring and summer until the next snowfall, which began a new year. The keeper memorized the names of the years in order, used the pictographs as memory aids, and also memorized other important events for each year. Thus the "keeper of the count" was the tribal historian. The history of the group was maintained in his memory to be recalled when needed. Other members of the tribe often remembered much of the information as well. When it became apparent that the keeper was nearing death, a successor was chosen to learn the required information and to continue the count.

One hundred years ago, the Bureau of Ethnology's annual report was presented to the Secretary of the Smithsonian Institution and included a description of the first Dakota winter count to be published in literature. It is known by the name of its keeper, Lone Dog, and begins in 1800 and ends in 1870 (Figure 3). More than 50 additional winter

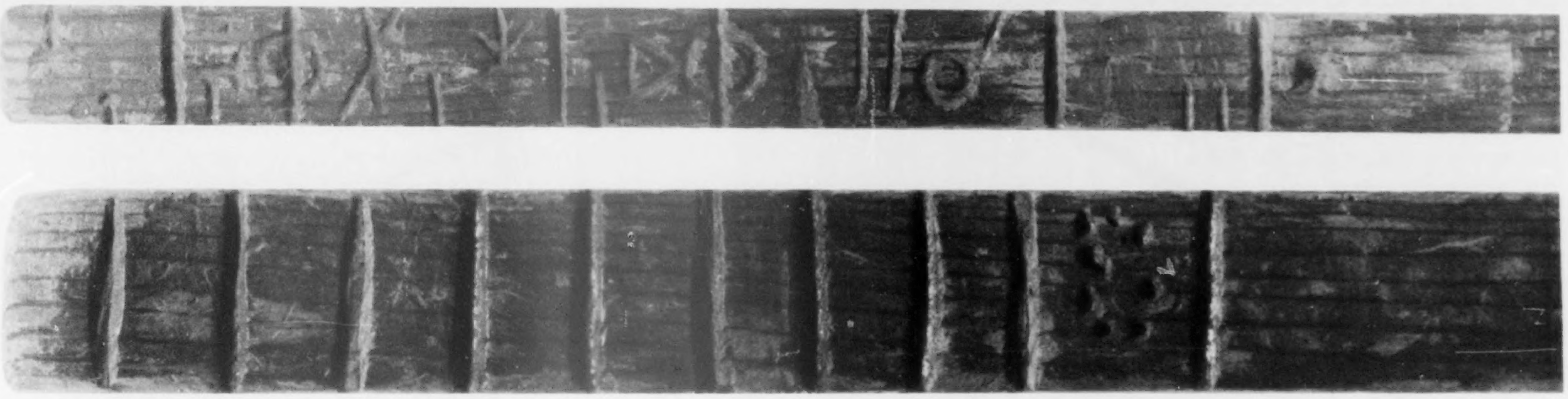
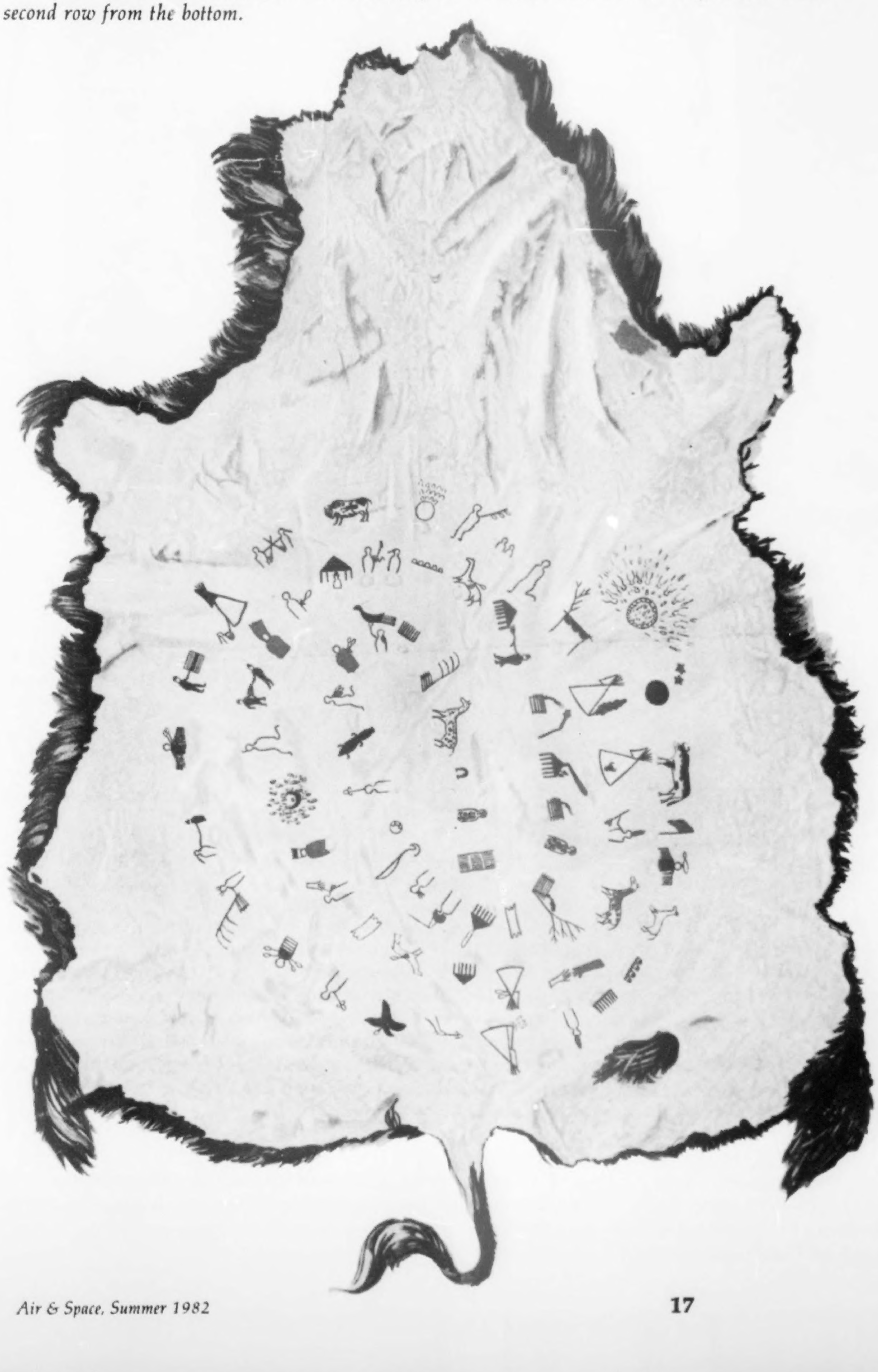


Fig. 2. Pima calendar sticks—Several Indian groups used counting sticks to record the passage of years as well as to count the days. These calendar sticks were marked each year when a particular season arrived. Interesting natural phenomena were sometimes remembered by the year marks. The most outstanding example is the great Lenoid meteor shower of November 1833 (bottom stick).

Fig. 3. Lone Dog, Dakota winter count—Painting symbols on a buffalo robe is the method used by the Dakota Indians for counting years. Economic, political, and astronomical events are depicted. The 1833 Lenoid meteor shower was recorded by the Dakotas and is shown at left center in the second row from the bottom.



counts have become known, most of them quite similar to the Lone Dog count. The symbols for each year are painted on a buffalo robe, beginning in the center and working outward in spiral fashion. Like the Pima calendar sticks, most of its features recall economic and political events. However, a few astronomical events are depicted. The picture for 1833, at the center of the second row from the bottom, shows a crescent moon surrounded by smaller features representing meteors; the famous Lenoid meteor shower.

The pictograph for the winter of 1821–22, near the center of the third row down from the top, shows a star with a bent trail extending from it. This represents a spectacular fireball witnessed by Indians in that region. Descriptions from the Lone Dog and other winter counts make it apparent that the sonic booms produced by the meteorite were heard by the Indians (see "Fireball," Fall Issue, *Air & Space* magazine). Some of the names for this year in other winter counts are: *Star-passed-by-with loud noise winter; When the moving star sounded; A-big-noisy-star-passed-winter; A moving star roared.*

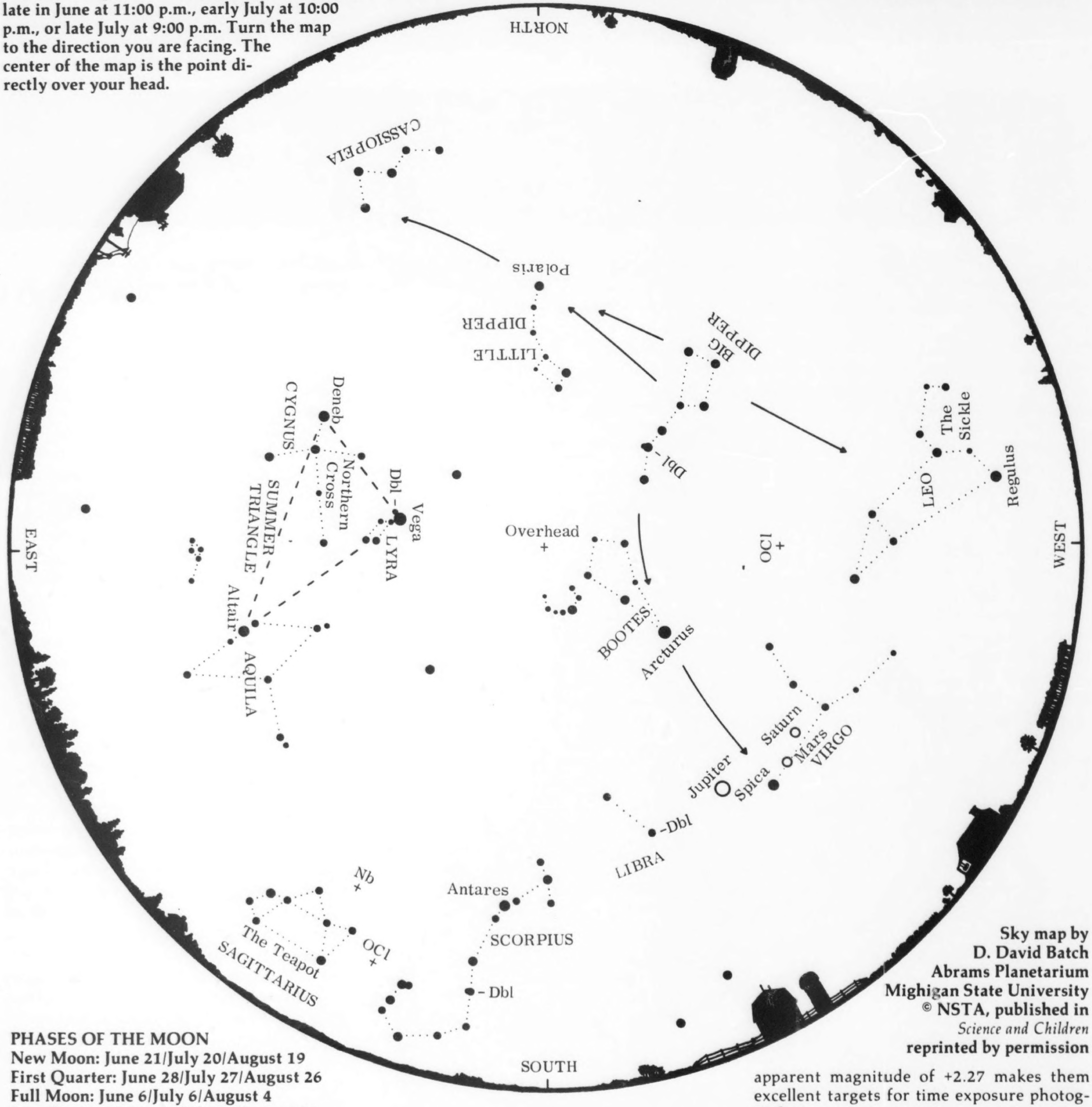
The event used to recall the winter of 1869–70, shown as the next to last year in the count, depicts the total solar eclipse that was visible in Dakota country August 7, 1869. The symbol shows the eclipsed Sun and two star images, possibly representing the planets Mercury and Venus, which were near the Sun at that time.

We have discussed two examples of how traditional cultures counted days and years. One, the horizon calendar, was used for planning the future, to know when it was time to plant, to hunt, to harvest, or to perform rituals. The other type, year counts, referred to the past as a form of historical record, a way of "writing" the passing years. Although the early practitioners of these methods did not know it, they were observing, recording, and learning to understand the cycles of the planet Earth in its orbit. ■

Summer 1982 Sky Map

T.H. Callen II
Production Specialist
Albert Einstein Spacearium, NASM

This circle represents the night sky as it appears late in June at 11:00 p.m., early July at 10:00 p.m., or late July at 9:00 p.m. Turn the map to the direction you are facing. The center of the map is the point directly over your head.


NORTH
CASSIOPEIA
Polaris
LITTLE DIPPER
BIG DIPPER
CYGNUS
Deneb
Northern Cross
SUMMER TRIANGLE
Dbl
Vega
LYRA
EAST
Altair
AQUILA
Overhead
BOOTES
Arcturus
Dbl
OCl
The Sickle
LEO
Regulus
WEST
Saturn
Mars
VIRGO
Jupiter
Spica
Dbl
LIBRA
Nb
Antares
SCORPIUS
OCl
The Teapot
SAGITTARIUS
Dbl
SOUTH

Sky map by
D. David Batch
Abrams Planetarium
Michigan State University
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Science and Children
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PHASES OF THE MOON
New Moon: June 21/July 20/August 19
First Quarter: June 28/July 27/August 26
Full Moon: June 6/July 6/August 4
Last Quarter: June 14/July 14/August 12

When looking at the night sky, we often look in different ways. At first we are struck by the sheer beauty and dazzle of the starfield, then the organized menagerie of the classical constellations and their legends, and finally the individual stars, clusters, nebulae, and galaxies residing within the star picture's boundaries.

While in high school, I was fortunate enough to have a teacher who had the skill and patience to be able to convey these different "levels of looking." A yearly event was the observation of the Perseid meteor shower. You may wish to observe the Perseids with your class.

The Perseids, also known as St. Laurence's Tears, will be at their maximum this year on August 12 (though you can still see them just before and after the 12th). Like December's Geminids and January's Quadrantids, they are famous for their regular return and constant numbers seen per hour. An observer will typically see about 50 Perseids per hour, including some fireballs. Faint Perseids are white or yellow, and brighter ones can be green, orange, or red. Some of the brighter meteors leave yellowish-colored trails that last up to 100 seconds after their ending in a flare or burst. Associated with dusty debris from Comet Swift-Tuttle, their apparent magnitude of +2.27 makes them excellent targets for time exposure photography.

The simplest way to observe a meteor shower is to find a dark location away from city lights, and bring a blanket to lie on. Although the best time to observe is after midnight looking toward the northeast, the last quarter Moon may interfere with optimal viewing. Encourage students to wear warm clothes. Parents of younger children may wish to attend as well; it may be their first experience of this kind too. I hope that you and your class have an opportunity to observe the Perseids this year. Not only will your class be taken with the celestial fireworks, but you may find yourself starting a tradition that will cause *you* to look at the sky in a different way too.

New Exhibit to Open at NASM

25 Years of Space Exploration

A new exhibit commemorating 25 years of space exploration opens July 1 at NASM. Through film, photographs, memorabilia, and samples of media accounts from the period, "25 Years of Space Exploration" will trace the development of the space age, placing events in social, political, and cultural contexts.

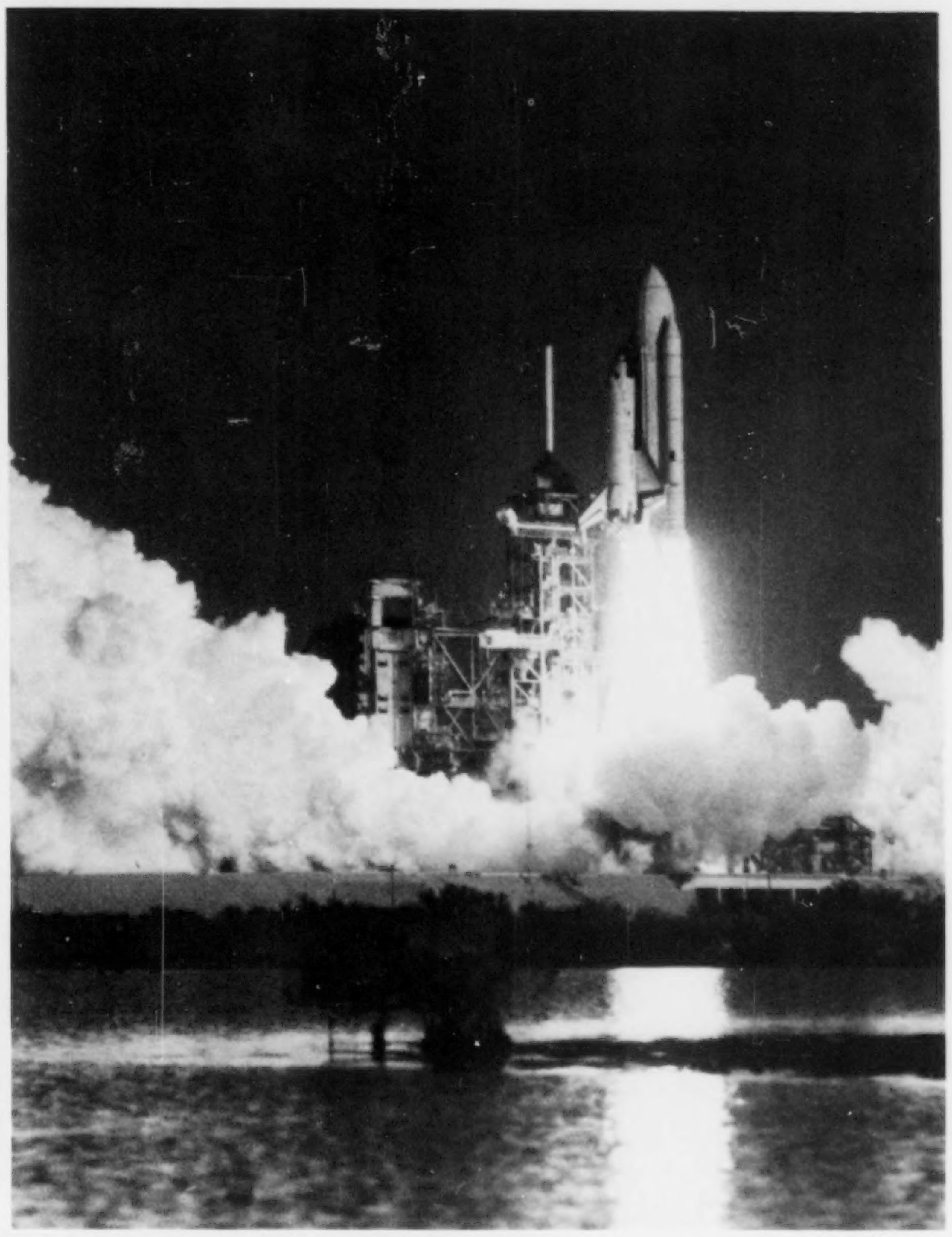
The exhibit will have five areas. Unit one, The Beginnings, will cover the period of the early satellites (1957-58); Man in Space (1961-64) will highlight the Mercury flights of Shepard and Glenn; Lunar Conquest (1966-69) describes the "race" to the Moon; Space is Commonplace (1972-76) begins with the launch of Pioneer 10 bound for Jupiter and includes Skylab and the joint U.S.-USSR Apollo-Soyuz Test Project, and the fifth unit, Today and Tomorrow, concentrates on the success and potential of the Space Shuttle.

The eight-month commemorative exhibit will be located in the Museum's Milestones of Flight gallery.

25 Years of Space Exploration

Bottom left: (left to right): Dr. Wernher von Braun, Dr. James Van Allen, and Dr. William Pickering display a model of Explorer 1 at a press conference after the successful launch in 1958.

Bottom right: Columbia *lifts off a few seconds past 7:00 a.m., April 12, 1981, at Kennedy Space Center, Florida.*



Index Volume 5, 1981-1982

Back issues of *Air & Space* are not available, but articles may be ordered from University Microfilms International, 300 N. Zeeb Rd., Ann Arbor, Michigan 48106.

This index is for Volume 5 of *Air & Space* (four issues published during the 1981-82 school year). The four issues, beginning in the Fall of 1981 are: Fall, Winter, Spring, and Summer.

Photo credits: Photos on pages 5 (top), 8 (bottom), 9-10, 12, 13-15, 19 (right), front and back covers, courtesy NASA. All other photos, courtesy NASM.

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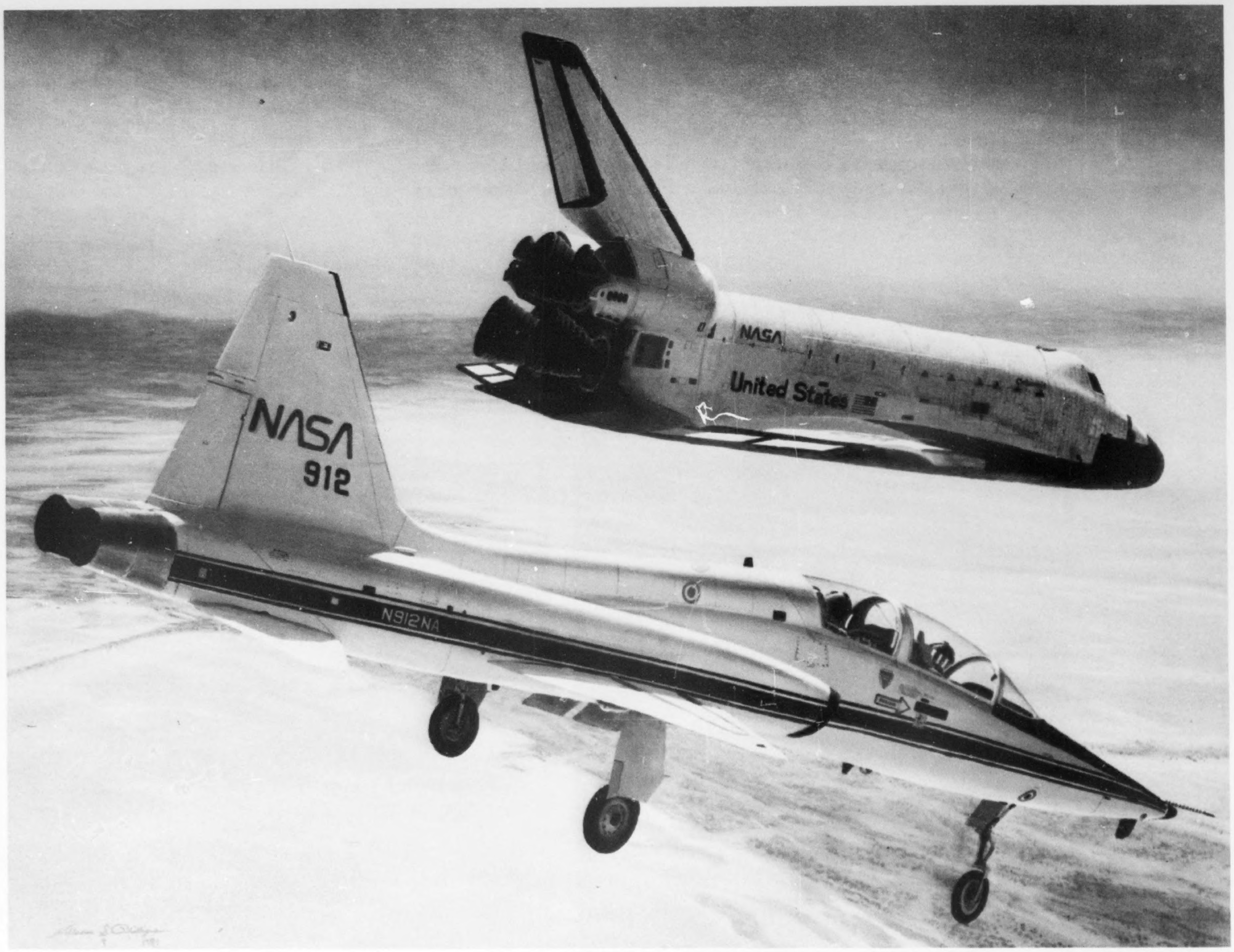

The Right Stuff, on Final, *an oil painting by artist William S. Phillips, depicts Space Shuttle* Columbia *and Chase 1 during the final moments prior to touchdown of the first landing of the* Columbia, *on April 14, 1981, at Dryden Flight Research Center, California. (For more fine art, see article on pp. 13–15.)*

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